MANUAL
of
GROUND SCHOOL TRAINING

FIFTH EDITION

Arranged by

J. R. K. MAIN

under the direction of the

Canadian Flying Clubs Association

Assistance from the following in the preparation of this Manual is gratefully acknowledged.

CIVIL AVIATION BRANCH, OTTAWA

ROYAL CANADIAN AIR FORCE

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FOREWORD

EXPERIENCE has shown the need for a thorough course of ground instruction to supplement the flying instruction so efficiently given by the flying clubs throughout Canada during the last seven years. The Canadian Flying Clubs Association was approached and, with customary diligence in meeting the Department's wishes, immediately accepted the responsibility for preparing a suitable course of lectures so that the instruction given in the ground schools to be organized by their various member clubs might be efficient, uniform and suitable for its purpose.

These lectures should be of the greatest value to the clubs in their work and it is hoped that student pilots will find the contents will increase their knowledge of how aircraft and engines function and other fundamentals in aeronautics.

The writer takes this opportunity of congratulating the editors on their work and the Association on another job well done and wishes the ground schools in all parts of the Dominion every success in their efforts to raise the standard of flying in Canada.

J. A. Wilson

Controller of Civil Aviation

December 1st, 1935.

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INTRODUCTION

THE aim of those responsible for the arrangement and preparation of these lectures is to prepare those desirous of securing pilots' licenses, for the necessary examinations.

Those wishing to study the various subjects pertaining to flying have heretofore been compelled to delve into a variety of text books and pamphlets in the hope of extracting from each one a little of the necessary information. This has discouraged many who, not knowing just where to turn for information, have been baffled in spite of their good intentions. It is hoped that this series of lectures will help, in a small way at least, to condense and consolidate the subjects treated so as to bring them within the grasp of those who are not in a position to do their own research work.

Experience has shown that the time limit of thirty hours is all that the average student can be expected to devote to the subject in one year. Within this time it has been possible to deal with the various subjects only in the most elementary way. It is hoped that the course will furnish the student with a comprehensive idea of the extent of his lack of knowledge, and perhaps spur him on to further efforts to remedy these defects. To that end, a list of books for further study is appended at the end of each lecture.

It is assumed that each club will make use of the best instructional material available among the members to present each subject. It must be distinctly understood that each lecture provides only a skeletal outline of the subject to be treated. To bring a group of students into a classroom and read a lecture over with them without the preparation necessary to expand and elaborate the subject, must bring both the teacher and the lecture under well deserved contempt.

A supreme effort should be made to give this work a practical aspect. Engines and rigging should present no difficulties since the students will be working with the machines before them. Theory of flight is prepared by one of the best qualified men in Canada, himself an accomplished pilot. He has treated the subject from a pilot's viewpoint, bearing in mind the problems that beset the beginner. In air pilotage it is necessary to lay the essential foundation in course plotting and insist on endless repetition to clinch the principles in the mind of the student. In discussing meteorology, an effort must be made to associate the discussion with conditions encountered in the locality. Indeed, papers prepared by different clubs dealing with local phenomena would be of great value to the whole flying fraternity.

Some of the clubs are making arrangements to use a convenient municipal school room in which to give instruction. This would appear to be an excellent idea since the school is usually centrally situated and the conditions of heating, lighting and equipment are of the best.

Some of the work on rigging, engines and compass swinging will have to be done in the hangar or in the open. For this reason it is suggested that, when a time-table is being drawn up, care should be taken to introduce these subjects at the time of year most favourable to outdoor work.

It will be noticed that space has been left after each subject for the student to enter his own notes and observations. Every student should be encouraged to do this.

SYLLABUS OF GROUND SCHOOL TRAINING

Treated under the following headings:

1.	Theory of Flight	5 hours
2.	Airmanship	2 hours
3.	Rigging	5 hours
4.	Engines	5 hours
5.	Air Pilotage	7 hours
6.	Meteorology	3 hours
7.	Air Regulations	3 hours
	Total time allotted	30 hours

THEORY OF FLIGHT — total time 5 hours

Equipment: one good model aircraft is of great assistance.

Lesson No. 1 — period of 1 hour. Mechanics and the aeroplane.

Lesson No. 2 — period of 1 hour. Airflow and the aerofoil.

Lesson No. 3 — period of 1 hour. The aeroplane, its equilibrium and stability.

Lesson No. 4 — period of 1 hour. Control: effect of speed on equilibrium, gliding, turning.

Lesson No. 5 — period of 1 hour. Aerobatics and some practical considerations.

AIRMANSHIP — total time 2 hours

Lesson No. 1 — period of 1 hour. Pilot's inspection before, during and after flight.

Lesson No. 2 — period of 1 hour. (a) Care of engines and aircraft. (b) Aids to cross country flying.

RIGGING — total time 5 hours

Necessary equipment: it is essential that this lecture be given with the aid of either a good model aircraft in the classroom or preferably with the use of a full scale airframe.

Lesson No. 1 — period of 1 hour. Definitions. Description and use of instruments. Methods of making measurements.

Lesson No. 2 — period of 1 hour. Rigging position. Erection and truing of centre section. Truing of main plane with fuselage, etc.

Lesson No. 3 — period of 1 hour. Rigging defects; cause and remedy.

Lesson No. 4 — period of 2 hours. Practical rigging demonstration.

ENGINES — total time 5 hours

Equipment: one engine, partly stripped or sectionized.

Lesson No. 1 — period of 1 hour. Definitions: names and descriptions of parts; four cycle principle.

Lesson No. 2 — period of 1 hour. Valve timing and timing diagram.

Lesson No. 3 — period of 1 hour. Wiring system and magneto.

Lesson No. 4 — period of 1 hour. Carburettor; mixture, altitude control, etc.

Lesson No. 5 — period of 1 hour. Lubrication systems; properties of oil.

AIR PILOTAGE — total time 7 hours

Equipment: the classroom should be provided with globe map of the world, ruler, and blackboard dividers. Each student must provide himself with protractor, one good scale ruler, and dividers. It is recommended that each club provide standard National Topographic Series, 4 miles to the inch (Air Edition) maps of the immediate vicinity for use in the classroom work.

Lesson No. 1 — period of 2 hours. Definitions. General features of maps and charts. Map projections, map scales. Conventional signs. Measuring angles and distances.

Lesson No. 2 — period of 2 hours. Navigation instruments; compass, airspeed indicator.

Lesson No. 3 — period of 2 hours. Practical course plotting using triangle of velocities; 2 point method, 10 degree method.

Lesson No. 4 — period of 1 hour. Practical compass swinging.

METEOROLOGY — total time 3 hours

Equipment: each student should be provided with standard weather chart issued by the Meteorological Service of Canada.

Lesson No. 1 — period of 1 hour. Terms and definitions; air properties; instruments; clouds and cloud types.

Lesson No. 2 — period of 1 hour. Reading the weather chart.

Lesson No. 3 — period of 1 hour. Practical hints concerning line squalls, ice formation, low visibility flying.

AIR REGULATIONS — total time 3 hours

Lesson No. 1 — period of 1 hour. Introduction to Air Regulations.

Lesson No. 2 — period of 1 hour. Examination paper.

Lesson No. 3 — period of 1 hour. Discussion on examination paper.

THEORY OF FLIGHT

FOREWORD

THE following lectures on the theory of flight have been prepared with a view to fulfilling the requirements of ground school training at Canadian flying clubs. In order that these lectures can be made of maximum utility and value to ground school students it is requested that instructors after using these notes, co-operate to the extent of suggesting any modifications and improvements in the matter of presentation of the subject, or in the exclusion or inclusion of subject matter, basing their suggestions on the degree of success which the lectures achieve in introducing the students to the subject of aero-dynamics and particularly its relationship to those practical problems of flight which will definitely be encountered by the club pilot.

It is recommended that students supply themselves with note books and that the lectures be given in such a way as to facilitate the taking of notes, as far as possible word for word, especially where definitions are being given. It will be of great value if the student can refer back in his notes to the fundamental definitions and principles when following the more advanced aspects of the subject.

THEORY OF FLIGHT

(1) Mechanics and the aeroplane.
(2) Airflow and the aerofoil.
(3) The aeroplane, its equilibrium and stability.
(4) Control; effect of speed and power on equilibrium; gliding; turning.
(5) Aerobatics and some practical considerations.

MECHANICS AND THE AEROPLANE

Lesson No. 1

Air Forces. When a body is in motion through the air, or when it is held at rest in a moving airstream, it experiences reactions which are known as air forces.

Aerodynamics. Aerodynamics is the name given to the study of the air forces acting on a body due to the relative motion of the body and the air.

Theory of Flight. This is the name given to that branch of applied aerodynamics which deals with the study of the air forces acting on an aeroplane when in motion through the air.

The theory of flight deals with:
(a) The determination of the air forces acting on the aeroplane.
(b) The effect of these forces on the behaviour of the aeroplane.

ELEMENTARY MECHANICS

Mechanics: is that branch of science which treats with the motion and equilibrium of material bodies.

Before the mechanics of the aeroplane can be considered a clear idea of the quantities involved is necessary.

Mass: the mass of a body is the quantity of matter in the body. The British standard of mass is the pound.

Inertia: is the resistance offered by a body to any change in its state of rest or motion.

Density: is a measure of the concentration of matter, that is, the mass contained in unit volume (lbs. per c.ft.).

Speed: is the rate of change of position with time measured by the distance moved over in unit time (feet per second or miles per hour).

Velocity: is the rate of change of position with time **in a given direction.** Speed takes no account of direction of motion; velocity is concerned with motion in specific directions.

Acceleration: is the rate of change of velocity with time, measured by the change of velocity in unit time (ft. per second, per second; miles per hour, per hour, etc.).

Momentum: is the product of the mass of a body and its velocity.

Force: is that which changes, or tends to change, the state of rest or motion of a body, measured by the rate of change of momentum with time.

force = rate of change with time of momentum.
= rate of change with time of (mass of body times velocity)
and since the mass of the body does not change,
force = mass of body times rate of change with time of velocity.
= mass of body times acceleration.

Thus, a force can also be defined by the product of the acceleration which it will produce in a body of given mass, and the mass of the body.

There are two British units of force — the Poundal and the Pound. The pound is 32.2 times as big as the poundal. The unit of force is that force which acting on the unit of mass will produce unit acceleration (unit velocity change in unit time).

Thus, a force of one poundal acting on a one pound mass will produce an acceleration of one foot per second, per second. Hence a force of one **pound** acting on a one pound mass produces an acceleration of 32.2 feet per second, per second.

It is more common to use the pound unit of force than the poundal.

The Moment of a Force is called the Torque and is the effectiveness of the force in producing rotation about a given point. It is measured by the product of the force and the perpendicular distance from the point to the line of action of the force (unit—the foot pound).

Weight: is the force with which a body is attracted toward the center of the earth (unit – the pound).

Centrifugal Force: is the name given to the outward force, acting on a mass in rotation. The force acts always perpendicularly to the path of rotation.

Work: when a force acts against a resistance to produce motion in a body the force is said to do work. Work is measured by the product of the force acting and the distance moved through against the resistance (British unit—one foot pound).

Power: is the rate of doing work – the number of foot pounds per second.

Horse Power: the British unit of power—550 foot pounds per second.

Pressure: is the force applied to or distributed over a surface measured as the force acting on unit area (pounds per square foot).

Energy: is the capacity for doing work. Units of energy are the same as for work.

Kinetic Energy: is the energy due to motion.

Equilibrium of Bodies: in considering the motions of bodies, we distinguish between two types of motion.

(1) Translational motion, or motion along a path either straight or curved.

(2) Rotational motion about some axis in the body.

In both these types of motion we recognize three states:

(1) A state of rest or no motion.

(2) A state of uniform motion in which the translational velocity or rotational velocity is unchanging with time.

(3) A state of accelerated motion in which the translational or rotational velocity is increasing with time.

Any body in either state 1 or state 2 is said to be **in equilibrium.**

When a body is at rest the forces on it must balance each other and leave no **resultant force.** If there is a resultant force the body will commence to move and accelerate (see definition of force).

If the forces on the body do not act through its centre of mass, then moments are present on the body. If the body is at rest the moments must balance and leave no **resultant moment.** If there is a resultant moment the body will commence to rotate. (See definition of moment).

In other words a body cannot remain at rest if it has a resultant force or moment acting on it because forces and moments produce linear and rotational accelerations respectively.

Similarly when a body is in uniform motion, that is, moving or rotating with **constant** velocity, there can still be no resultant force or moment acting upon it, because if there were, the body would accelerate (linearly or rotationally).

When, however, a body is in the third state, moving with accelerated motion, there must be some resultant force or moment which is giving rise to the acceleration, and by our definition of force, the magnitude of the force or moment is proportional to the acceleration.

Examples:—

(1) When an aeroplane is flying along with uniform velocity and constant altitude, there is no resultant force or moment acting on it. The weight acting vertically downwards is just balanced by the lift on the wings acting vertically upwards. The force of air resistance acting backwards is just balanced by the thrust of the airscrew or propeller acting forwards. The aeroplane is in equilibrium.

If the lift decreases for any reason it will become insufficient to balance the weight, a resultant force will therefore be acting downwards with the result that the aeroplane will commence to sink downwards. If the lift increases to a value more than the weight, the aeroplane will climb due to a resultant force acting **upwards**, the acceleration produced in a body by a force always taking place along the line of action of the force.

(2) When an aeroplane departs from straight and level flying and commences to make a turn it is accelerating in rotation, and hence fits into the third state of motion classified above. A resultant moment must therefore be acting on the aeroplane to produce this acceleration in rotation and this is of course the case, the pilot applying the moment on the aeroplane by means of the rudder.

As the aeroplane commences to accelerate in rotation, air forces on the aeroplane are called into play which create an opposite turning moment on the aeroplane. When this opposite moment equals the moment due to the rudder, the two moments balance each other and since there is no resultant moment the **acceleration** ceases and the aeroplane continues turning with a **uniform** velocity.

The aeroplane then continues in this state of uniform rotation until the pilot uses the rudder to apply a moment in a direction which opposes the rotation and the aeroplane immediately comes out of the turn.

A very condensed outline of the principles underlying the equilibrium of bodies has now been given together with a few examples. These examples and many more besides can be readily understood by reference to Newton's Laws of Motion, which sum up concisely the principles of equilibrium already outlined.

Newton's Laws of Motion.

1. Every body continues in its state of rest or of uniform motion in a straight line except insofar as it may be compelled to change that state by the action of some outside force.

2. Change of motion, or momentum, is proportional to force applied and takes place in the direction of the line of action of the force.

3. To every action there is always an equal and opposite reaction.

A thorough understanding of the foregoing elementary mechanics will be of the greatest service to the student in his study of the behaviour of the aeroplane and the theory of flight. We now pass on to a consideration of the aeroplane itself.

THE AEROPLANE

The names of the various parts of a typical aeroplane are given in Fig. 1, which is a three view drawing of a single seater tractor biplane.

The Fuselage: is the main structure or body of the aeroplane, to which the main planes, tail unit and other surfaces are attached. At its forward end it houses the **engine** whose function is to rotate the **airscrew** or **propeller**, which when rotating experiences an air force in a forward direction and so urges the aeroplane through the air. Behind the engine, spaces are set aside in the fuselage for housing the crew. These spaces are known as the **cockpits** and contain the necessary seats, controls and instruments required in the operation of the aeroplane.

The Wings or Main Planes: are attached to the fuselage at points near the cockpits. The wings are usually fabric covered structures which, on account of the air forces experienced by them due to the speed of the aeroplane through the air, provide a vertical lifting force which balances the weight of the aeroplane, thus fulfilling one of the requirements for the equilibrium of the aeroplane in flight. An aeroplane may have only one wing (monoplane) made up of two halves disposed on either side of the fuselage and referred to as the **port** or **left** wing, and the **starboard** or **right** wing as viewed from the cockpit.

A biplane has two wings as shown in Fig. 1; the bottom wing is attached to the fuselage directly at its **roots** and the top wing is attached to the lower wing and to the fuselage by a system of **struts** and **bracing wires,** consisting of **interplane struts** and **centre section struts** and **lift or flying wires** and **anti lift or landing wires.** When in flight the weight of the fuselage is supported by the wings.

The function of the lift wires is to help transfer the weight of the fuselage to the wings. When on the ground the weight of the wings is supported by the fuselage and the function of the anti lift wires is to transfer the wing weight to the fuselage.

The Centre Section: is that portion of the top wing directly above the fuselage and rigidly connected to it by means of the centre section struts and suitable bracing wires. The outer portions of the wing are usually removable and are suitably bolted to the centre section.

At the rear end of the fuselage is the **tail unit** or **empennage,** consisting of certain wing-like surfaces which are necessary for stability and control. The **tailplane** is a horizontal stabilizing surface which experiences

a small lifting force of the same nature as the main plane lift. The function of this force is to provide a moment on the aeroplane which will balance any existing moments due to the relative positions of the wing lift and the **centre of gravity** of the aeroplane, the point through which the weight of the aeroplane can be considered to act.

The tailplane is thus a means of ensuring that there will be no **resultant** moment on the aeroplane, which from our treatment of elementary mechanics we know to be one of the requirements for equilibrium in flight.

The rear part of the tailplane consists of the **elevators** which are movable surfaces under the control of the pilot — hinged to the tailplane at their forward edge. By changing their position relative to the tailplane the pilot can vary the amount of tailplane lift and thereby call into play moments which can change the fore and aft attitude of the aeroplane.

In a similar manner directional stability and control are obtained from the air forces acting on the fixed stabilizing fin and the movable rudder.

At the rear edges of the wings are further movable control surfaces called the **ailerons**, which move in opposite directions, as one goes up the other is depressed. The ailerons, when moved, decrease the wing lift on one side and increase the wing lift on the other side of the aeroplane. In other words, a moment is called into play which tends to rotate the aeroplane. This rotation is called **rolling** or **banking** and the moment which produces it is known as a **rolling moment.**

The **undercarriage** and the **tail skid** are the structural members upon which the aeroplane rests when on the ground, and on which it makes its preliminary run in acquiring sufficient "flying speed" to become airborne.

AIRFLOW AND THE AEROFOIL

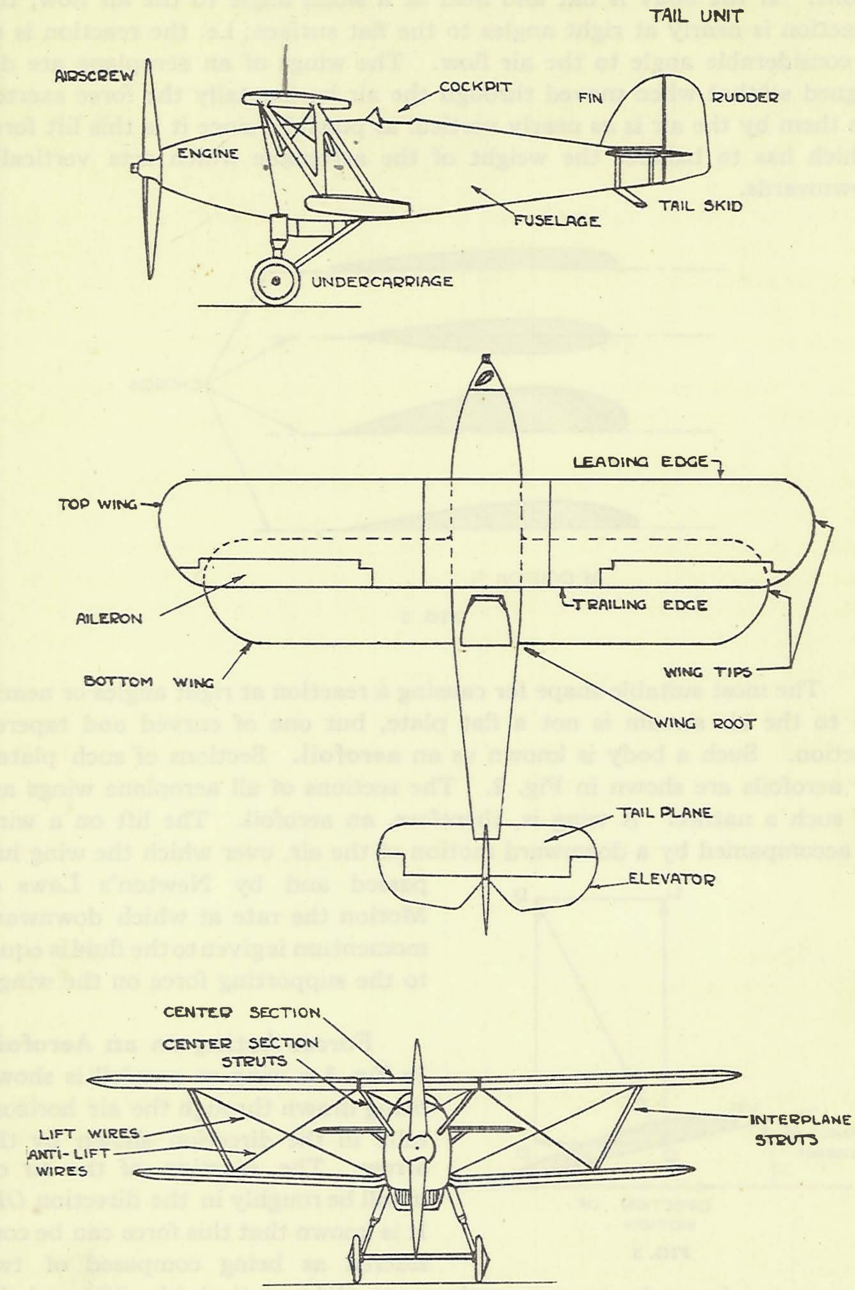
Lesson No. 2

Air Speed. The speed of an aeroplane relative to the air is called its air speed, and agrees with the actual speed over the ground **(ground speed)** only if the aeroplane is flying in still air. It must be realized at once that it is the **relative speed** upon which the air forces depend.

Air Forces. The magnitude and direction of the air forces on a body due to its motion relative to the air depend on the size and shape of the body and on the velocity relative to the air.

The force or reaction of the air on the body is due partly to the deflection of the air around the body and partly to the viscous nature of the air, some of which tends to adhere to the body and retard its motion. This retarding force on the body is known as "skin friction". The effect of the body is, therefore, to change the momentum of the air relative to it, due to the change in speed and direction of the air particles. The reaction experienced by the body in consequence of this is exactly equal to the rate of change of momentum in the air stream passing the body.

FIG. 1



TAIL UNIT
AIRSCREW
COCKPIT
FIN
RUDDER
ENGINE
TAIL SKID
FUSELAGE
UNDERCARRIAGE
LEADING EDGE
TOP WING
AILERON
TRAILING EDGE
BOTTOM WING
WING TIPS
WING ROOT
TAIL PLANE
ELEVATOR
CENTER SECTION
CENTER SECTION STRUTS
INTERPLANE STRUTS
LIFT WIRES
ANTI-LIFT WIRES

If the body is of irregular shape, such as a stone, the reaction on it is nearly in the same direction as the air flow and acts backwards on the stone. If the body is flat and held at a small angle to the air flow, the reaction is nearly at right angles to the flat surface; i.e. the reaction is at a considerable angle to the air flow. The wings of an aeroplane are designed so that when moved through the air horizontally the force exerted on them by the air is as nearly vertical as possible, since it is this lift force which has to balance the weight of the aeroplane which acts vertically downwards.

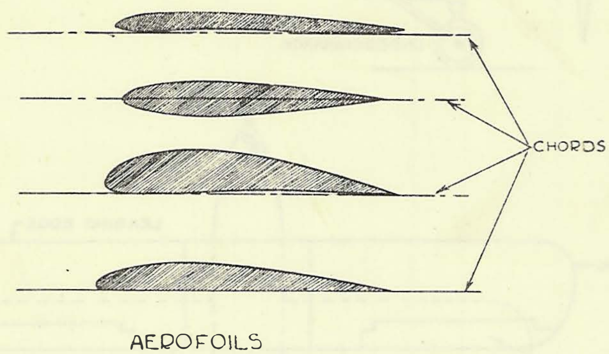


FIG. 2

The most suitable shape for causing a reaction at right angles or nearly so to the air stream is not a flat plate, but one of curved and tapered section. Such a body is known as an **aerofoil.** Sections of such plates, or aerofoils are shown in Fig. 2. The sections of all aeroplane wings are of such a nature. A wing is, therefore, an aerofoil. The lift on a wing is accompanied by a downward motion of the air, over which the wing has passed and by Newton's Laws of Motion the rate at which downward momentum is given to the fluid is equal to the supporting force on the wings.

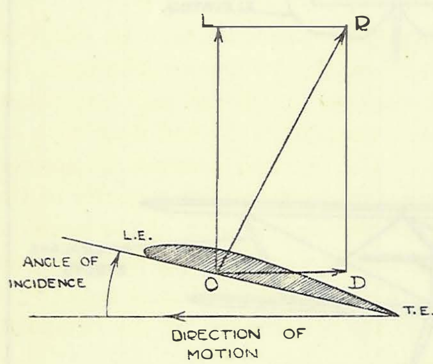


FIG. 3

Forces Acting on an Aerofoil. In Fig. 3 a wing or aerofoil is shown being drawn through the air horizontally in the direction shown by the arrow. The reaction of the air on it will be roughly in the direction *OR*. It is known that this force can be considered as being composed of two forces at right angles to one another; one (*OL*) vertical (the lift) and the other (*OD*) horizontal (the drag). The drag is a force directly opposed to the motion of the aerofoil, and must be overcome by power expended by the engine. It is, therefore, desirable that this force be as small as possible. In other words (*OR*) must be as nearly vertical as possible.

DEFINITIONS

Leading edge: The front edge of the aerofoil, which meets the air first, is called the leading edge.

Trailing edge: The rear edge of the aerofoil, where the air leaves it, is known as the trailing edge.

Chord: The straight line which touches the concave under surface of the aerofoil at or near the leading and trailing edges is known as the chord. In the case of some aerofoils both upper and lower surfaces are convex (See Fig. 2) and in such cases the chord is taken as the line joining the centres of curvature of the leading and trailing edges. (See Fig. 4).

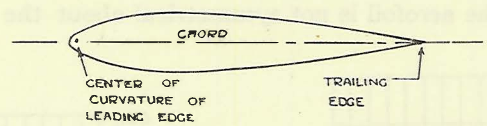


FIG. 4

Angle of Incidence: is the angle between the chord of the aerofoil and the direction of the air flow past it (taken as positive when the upper surface of the aerofoil is on the opposite side of the chord from the line representing the air flow).

Centre of Pressure: The point (O) where the line of action of the resultant force (OR) cuts the chord is known as the centre of pressure (C.P.). For a given aerofoil the centre of pressure moves to and fro along the chord, depending on the angle of incidence. As the angle of incidence is increased the C.P. moves towards the leading edge and as the incidence decreases the C.P. moves towards the trailing edge. The reverse is the case for a flat plate, as the incidence decreases the C.P. moving towards the leading edge.

Variation of the Forces with Change of Incidence: In addition to the movement of the centre of pressure as the incidence is changed, the magnitude of the air reaction OR also changes and hence its components the lift and the drag, also change. These changes of lift and drag with incidence are of the greatest importance. The lift and drag on an aerofoil depend not only on the angle of incidence, but also on the velocity of the airstream, the density of the air, and on the size or area of the aerofoil. The variation with velocity is such that the forces of lift and drag are proportional to the square of the velocity. For a given aerofoil of area (S) in a given velocity (V) of air of density (ρ) the lift is given by the equation:

$$L = K_L \rho S V^2$$

where K_L is a constant depending on the angle of incidence. Similarly the drag is given by

$$D = K_D \rho S V^2$$

K_L and K_D are known as the lift and drag coefficients respectively.

It will be seen then that a given lift can be obtained with either a large velocity (V) and a small area (S) or a small velocity and a large area.

We now wish to study the changes of lift and drag with change of incidence for a given aerofoil moving in an airstream of given velocity. In other words the values V, S and ρ will be unchanged while we study the variations due to changing incidence. Obviously from our equations above, if ρ, S and V are to be unchanged, the changes in L and D as a result of changing incidence will be due solely to changes in K_L and K_D. In other words if we study the effect of incidence on K_L and K_D we are really studying the effect of incidence on L and D.

In Fig. 5 a graph is given, showing the variation of K_L with incidence for a typical aerofoil. We notice first of all that when the aerofoil is at zero incidence it is still giving some lift and that the lift does not become zero until some small negative angle of incidence is reached. This is due to the fact that the aerofoil is not symmetrical about the line joining the

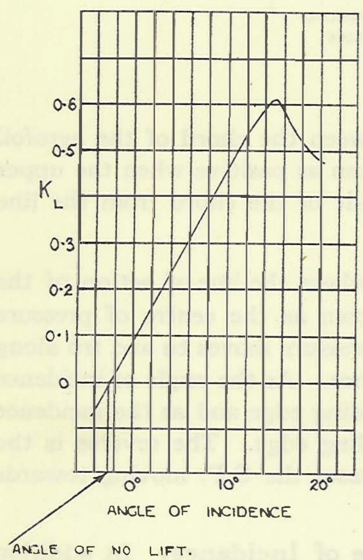


FIG. 5

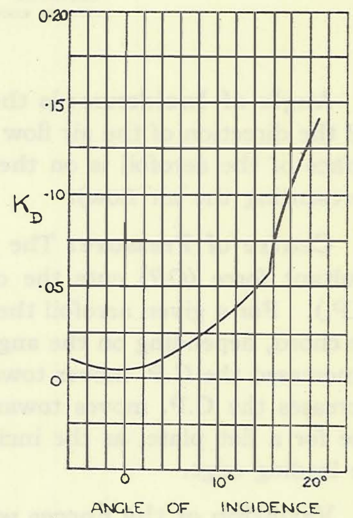


FIG. 6

leading and trailing edges, but is cambered. Some aerofoils are symmetrical, the upper and lower surfaces being convex and the line joining the leading and trailing edges then splits the aerofoil into halves. In the case of such an aerofoil the lift is zero when the incidence is zero, as would be expected. Our second observation from the graph is that the lift increases rapidly as the incidence is increased until an angle of some 15° or so is reached when the lift is a maximum, after which increasing the incidence causes the lift to decrease suddenly. This characteristic of aerofoils is of vital importance and is referred to as the **stall.** The angle at which the lift is a maximum is known as the **stalling angle** or **critical angle.**

Fig. 6 shows the variation of the drag coefficient with incidence. From a minimum value at an angle corresponding closely to the angle of no lift, the drag increases rapidly especially as the aerofoil approaches the stalling point.

Thus, although it is desirable to obtain as much lift as possible from the aerofoil, this cannot be done without increasing the drag. If we plot the ratio lift/drag against incidence we have a measure of the efficiency of the wing and we can find the incidence at which the wing produces a given lift for the smallest expenditure of energy in overcoming drag (L/D a maximum).

In Fig. 7 the L/D ratio has been plotted for the same aerofoil for which the K_L and K_D curves are given. It will be seen that the lift/drag is a maximum at about $+\ 3°$ incidence.

Reverting to the equation for the lift $L = K_L \rho S V^2$, for a given aeroplane of weight (W) and wing area (S), equilibrium in level flight is possible when $L = W$.

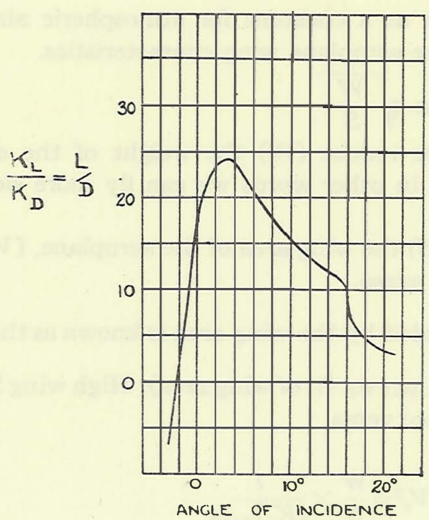


FIG. 7

Now this value of the lift can be achieved by flying at high speed (V large) and a small angle of incidence (K_L small). If the pilot wishes to fly more slowly (V smaller) enough lift to balance the weight and give equilibrium in level flight can be obtained by increasing the angle of incidence (K_L larger). This process of reducing V and increasing incidence, and hence K_L, can be carried on until a certain minimum speed is reached beyond which a reduction in speed cannot be counterbalanced by an increased incidence, because increasing the incidence causes K_L to fall instead of rise. This takes place, of course, as soon as the angle of maximum lift is reached. This minimum speed at which level flight can just be maintained is called the **stalling speed** for that particular aeroplane. Any attempt to still further reduce the speed by increasing incidence causes a loss in lift and the aeroplane will drop.

The sudden loss of lift is usually rendered more serious by the correspondingly sudden increase in drag of the aeroplane at the stall which of course tends to slow up the aeroplane still further and since reducing

the speed led to the stall, further reduction of speed only makes the conditions worse and more difficult to correct.

From our lift equation we are able to examine the factors which affect the stalling speed of an aeroplane in level flight.

$$L = K_L \rho S V^2$$

Now for horizontal flight $L = W = K_L \rho S V^2$ where W equals weight of aeroplane.

Now when (V) has fallen to the stalling speed (V_S)

(K_L) has risen to its maximum value $(K_L)_{max}$.

Hence $W = (K_L)_{max} \rho S V_S^2$

or $V_S^2 = \frac{W}{S} \times \frac{1}{(K_L)_{max} \rho}$

Now ρ can be taken as a constant for atmospheric air at sea level, and $(K_L)_{max}$ is fixed by the aeroplane wing characteristics.

Therefore V_S varies as $\sqrt{\frac{W}{S}}$

In other words if we reduce (W) the weight of the aeroplane, the stalling speed is reduced, in other words we can fly more slowly and vice versa.

Also, if we increase (S) the wing area of the aeroplane, (V_S) the stalling speed is reduced and vice versa.

$\left(\frac{W}{S}\right)$ the weight divided by the wing area is known as the wing loading (weight in pounds carried per sq. ft. of wing area). High wing loading means high stalling speed and vice versa.

From the equation

$$V_S^2 = \frac{W}{S} \times \frac{1}{(K_L)_{max} \rho}$$

we can at once see the effect of altitude on the stalling speed of the aeroplane.

As the altitude above the earth is increased ρ the air density **decreases.** Hence for a given aeroplane W, $(K_L)_{max}$ and (S) being fixed,

$$V_S^2 \text{ varies as } \frac{1}{\rho}$$

and if ρ decreases V_S must increase. In other words an aeroplane stalls at a higher speed at higher altitudes.

The airspeed indicator reading on the pilot's instrument board, however, is subject to an error due to change in air density with height. This error is such that the instrument reads low at high altitudes and the stalling speed as indicated on the instrument is unchanged with height. If an aeroplane stalls at 40 mph at sea level then at 10,000 feet the aeroplane will still stall when the instrument just reads 40 mph., although the true airspeed will be greater than this value. This must be borne in mind in operating from mountain aerodromes where, due to high altitude, stalling speeds are higher.

Before leaving the question of stalling speed one additional observation can be made from the equation

$$V_s^2 = \frac{W}{S} \times \frac{1}{(K_L)_{max} \rho}$$

The stalling speed depends on the maximum lift coefficient $(K_L)_{max}$. Now $(K_L)_{max}$ varies slightly from one aerofoil section to another, the extreme range probably being from about 0.4 to 0.8. If low landing speed is required, (V_s the stalling speed is often referred to as the landing speed), then obviously from the equation, $(K_L)_{max}$ must be as high as possible and the designer will choose a "high lift" aerofoil, providing it does not possess other features which are undesirable (too high a drag coefficient for instance). Several devices such as the automatic slot and the wing flap can now be fitted to a wing which will increase the $(K_L)_{max}$ far above the normal values, and hence allow very material reductions in landing speed. Such devices will be referred to in more detail later on.

Airflow: Air is a fluid and "flows" in a general way like any other fluid, water for instance. When a fluid flows past a body or when a body moves through a fluid, the resulting flow may be one of two kinds, **smooth** or **eddying** depending on the shape or attitude of the body to the fluid stream. For instance, if a flat plate is dragged broadside on through water, large eddies or whirlpools can be seen in the wake of the plate — the flow is eddying; whereas, if the body is boat shaped and dragged through the water it will be seen that the water flows smoothly past the sides of the body with but little eddying motion in the wake. Air behaves in exactly the same way in flowing past bodies.

Streamlines: If the airflow is steady or **smooth** (it does not vary from moment to moment) the type of flow can be illustrated by a simple diagram, lines being drawn to represent the paths followed by the air particles round the body. Such lines are called streamlines and Fig. 8 is a typical flow pattern illustrating the smooth flow past a symmetrical aerofoil section at 0° incidence.

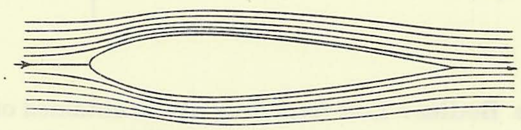


FIG. 8

Viscosity and Skin Friction: It has been mentioned earlier that the viscosity of the air (a property possessed by all fluids) gives rise to frictional forces between the air and the body moving through it, the air being retarded while the body experiences a surface resistance. This resistance we call **skin friction** and always forms a part of the total resistance or drag whether the flow is smooth or eddying.

As the air moves past the surface of the body the particles of air touching the surface are completely brought to rest. The air particles in the next layer are in motion over the first layer and frictional or viscous

forces arise between the two layers which retard slightly the second layer. The third layer is then moving a little faster than the second and the relative motion results in viscous forces retarding the third layer and so on. This process continues, the retardation diminishing as the distance from the surface increases. Actually the viscosity effects are so small that they are felt only in a very narrow region near the surface of the body. In the case of an aerofoil the thickness of the region is probably only a few thousandths part of the chord. The varying velocity in this region, which is known as the **boundary layer** causes the streamlines to crumple up and form eddies. The surface of the aerofoil is, therefore, covered by a thin sheet of eddies or vortices, and the energy carried away by these vortices represents the work done in forcing the aerofoil through the air against its "skin friction".

Form Drag: In addition to skin friction there is another type of resistance experienced by a body which depends not on the extent of the surface but on the shape of the body. It is due essentially to the amount of eddying flow present and the formation of vortices in the wake. These vortices are continually carrying away energy from the body, which, therefore, experiences a resistance called **form drag.** The form drag appears as a pressure force due to unequal air pressures at the front and rear of the body.

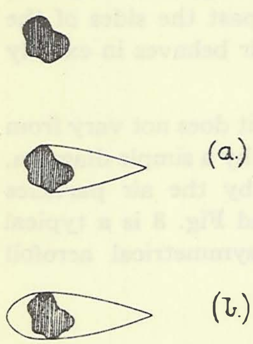


FIG. 9

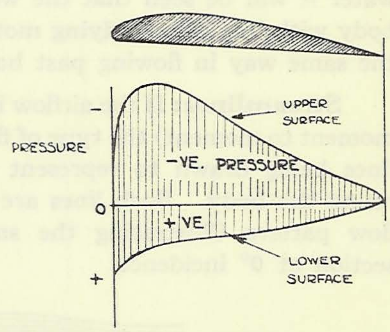


FIG. 10

Streamline Bodies: Low form drag can be obtained only if the region of eddying flow is reduced to a minimum. This can be obtained in two ways — firstly by adding a nice fish-like tail fairing to the body (Fig. 9a) and secondly by adding a smooth rounded nose (Fig. 9b) which allows a better entry for the body in the air stream, the whole giving smooth deflection of the streamlines around the body. This "streamlining" very much reduces the large form drag. The slight increase in skin friction due to greater surface is almost negligible in comparison.

A body in which the form drag has been practically eliminated is called a **streamline body.** All parts of aeroplanes are streamlined as far as possible. A length to breadth ratio (known as "fineness ratio") of about 3½ to 1 appears to give minimum resistance.

Airflow over an Aerofoil: At small angles of incidence an aerofoil is a good streamline body but as the incidence increases it presents a bluff shape to the airstream and form drag is developed. Fig. 6 shows how drag increases with incidence.

At low angles of incidence the flow over the upper surface is **smooth.** In following the curved contour of the upper surface the air particles experience a centrifugal force acting upwards away from the surface. As a result a suction or negative pressure is produced over the whole of the upper surface which tends to lift the aerofoil. At the same time the air exerts an upward pressure on the lower surface. Both the suction on the upper surface and the pressure on the lower surface contribute to the lifting force on the aerofoil, but the suction is the more intense of the two and provides the major portion of the lift.

Fig. 10 shows a typical pressure distribution diagram for an aerofoil. Notice that the suction or negative pressure is greater than the positive pressure on the lower surface. Also the suction is most intense at a position on the upper surface near the leading edge of the aerofoil.

As the incidence of the aerofoil is increased the air flowing over the upper surface has to turn through a much sharper angle in order to be able to follow the contour of the surface right to the trailing edge. Eventually the incidence becomes so high that the air is unable to make the turn and the flow breaks away from the surface. This takes place at the stalling

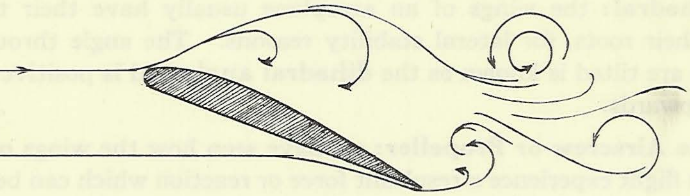


FIG. 11

angle. Viscosity which retards the air on the upper surface causes dead air to be piled up which hinders the oncoming air and renders it impossible for the air stream to follow the contour of the surface. As soon as the flow breaks away the flow pattern is no longer smooth and streamline, but changes to eddying. The form drag rapidly rises and the mechanism by which lift was produced at the lower incidences can no longer take place so that the lift falls.

Fig. 11 shows the type of flow now existing.

This very brief outline of the flow around an aerofoil is intended to show what happens with changing incidence and to explain the characteristics of the lift and drag curves of Figs. 5 and 6.

In addition to the air resistance or drag of the wings, there is the drag of the remaining parts of the aeroplane; fuselage, landing gear, tail unit, struts, wires, etc. This drag is usually referred to as the **parasite drag.** It is again composed of skin friction and form drag and must be kept to the bare minimum by careful streamlining.

THE AEROPLANE, ITS EQUILIBRIUM AND STABILITY

Lesson No. 3

THE AEROFOIL IN THE AEROPLANE

Aspect Ratio: the plan form of an aeroplane wing is defined by its aspect ratio. For a rectangular wing this is given by the **span** divided by the **chord.** The chord has already been defined, the **span** is the overall distance from wing tip to wing tip.

The Camber: is the convexity of the aerofoil section used, usually measured (as a fraction of the chord) by the maximum height above the chord. (Upper surface camber, lower surface camber and mean camber — the camber of the centre line which lies half-way between the upper and lower surfaces).

Stagger: in order to improve a pilot's view, or from considerations of stability, it is desirable to have one wing of a biplane forward of the other. The distance of one wing in front of the other is called stagger. The stagger is said to be **forward** or **positive** if the top wing is in front of the bottom one and backward or negative if the bottom is in front of the top. **Gap,** is the distance between the planes of a biplane, measured from chord to chord and at right angles to them.

Dihedral: the wings of an aeroplane usually have their tips lifted above their roots, for lateral stability reasons. The angle through which the tips are tilted is known as the **dihedral angle** and is positive when the tilt is upwards.

The Airscrew or Propeller: we have seen how the wings of an aeroplane in flight experience a resultant force or reaction which can be considered as being composed of two forces at right angles, the lift acting vertically upwards and the drag acting horizontally backwards. When the aeroplane is in steady flight the lift just balances the weight acting downwards. From what has been said on the subject of equilibrium it is evident that there must be some forwardly acting force which just balances the drag in order for the aeroplane to be in equilibrium. This forward force is supplied by the airscrew which converts the power of the engine into a forward thrust.

An airscrew is in essence a rotating wing which develops a lift at right angles to the plane of rotation. The airscrew throws air backwards in a continuous stream in order to produce this forward thrust. This stream of air from the propeller is called the **slipstream.** Although the width, the thickness and degree of twist of the blades of an airscrew vary along their length the section of the blade at any point is of aerofoil section, usually with a flat undersurface. Airscrews are called **tractors** or **pushers,** according as they are placed in front of or behind the engine.

The Boss: is the central portion of the propeller from which the blades project.

The Hub: is the metal fixing to which the boss is attached, by means of which the propeller is fitted to the engine.

The Blade Root: is that portion of the blade adjacent to the boss.

The Blade Tip: the point of the blade most distant from the centre. The distance of the blade tip from the centre of the propeller is called the **tip radius** or simply the **propeller radius.**

The Diameter: is the distance from tip to tip.

The Aspect Ratio: of a propeller is the ratio: $\dfrac{\text{tip radius}}{\text{maximum blade width}}$

The Blade Angle: at any section is the angle made by the face or under surface of that section to the plane of rotation. (See Fig. 12.)

The Leading and Trailing Edges: are self-explanatory. The cambered side of the blade is the **"back"** and the flat side is known as the **"face"** or **"working-face".**

A propeller is **"right-hand"** if, when viewed by an observer standing behind the aircraft, it is rotating in a clockwise direction. The propeller is **"left-hand"** if from the same position it is rotating in an anti-clockwise direction.

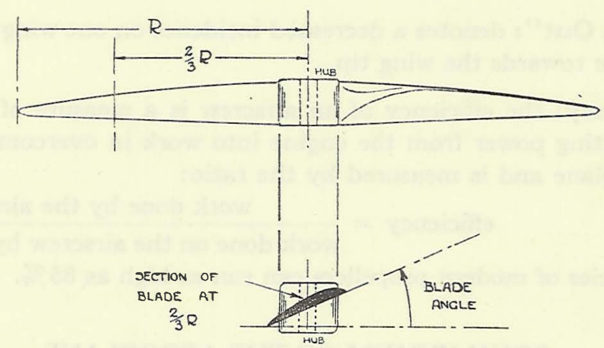


FIG. 12

The Pitch of a Propeller: The pitch of a body rotating about an axis and simultaneously moving along that axis is the distance travelled forward during the time taken for one revolution. According to this definition the pitch of a propeller would be the distance travelled by the aircraft during the time taken for one revolution of the propeller. The aircraft, however, may be made to travel at different speeds with the same engine and propeller revolutions by merely climbing or diving it. By the above definition, therefore, the same propeller may have various pitches in various differing circumstances.

It is usual to employ two terms to define the pitch of an airscrew:

(A) **The Experimental Mean Pitch:** this is the distance which the propeller must travel along its axis in the time taken for one revolution in order for the whole propeller to give **no thrust.**

(B) The Geometric Mean Pitch: this is calculated from the angular setting (or **blade angle)** of the section of the blade two thirds the way along the blade, in exactly the same way as the pitch of an ordinary screw thread is calculated from the pitch angle of the threads.

The blade angle is measured to the working face, as shown in Fig. 12.

The Torque: of an airscrew is its resistance to rotation. It is equivalent to the drag of an ordinary aerofoil and acts circumferentially owing to the rotation of the airscrew.

The torque of the airscrew is overcome by the power of the engine. In rotating the airscrew the engine experiences a reaction tending to rotate it, and hence the aeroplane to which it is bolted, in the opposite direction to that of the airscrew. This can be overcome by giving the wings on one side of the fuselage a slightly greater or less incidence than on the other, thus calling into play a lateral rolling moment to balance the torque reaction and provide equilibrium.

"Wash In": is an expression used to denote an increased incidence on one wing, or an increasing angle of incidence towards the wing tip.

"Wash Out": denotes a decreased incidence on one wing or a decreasing incidence towards the wing tip.

Efficiency: the efficiency of an airscrew is a measure of its capacity for transmitting power from the engine into work in overcoming the drag of the aeroplane and is measured by the ratio:

$$\text{efficiency} = \frac{\text{work done by the airscrew}}{\text{work done on the airscrew by the engine}}$$

The efficiencies of modern propellers can run as high as 85%.

EQUILIBRIUM OF THE AEROPLANE

With the lift balancing the weight and the airscrew thrust balancing the drag due to forward motion, the aeroplane is well on the way to being in a state of equilibrium. From our treatment of mechanics, however, there appears still one more condition to be fulfilled before equilibrium is obtained. There must be no resultant moment on the aeroplane. If there is, the aeroplane will commence to rotate and equilibrium will be destroyed.

An aeroplane is so designed that its centre of gravity (C.G.)—the point through which its weight can be considered to act is as close as possible to the region of the centre of pressure on the wings. In the case of a biplane the forces on the two planes can be considered to be combined into one force and the point where this single force cuts the **"equivalent plane"** (chosen between the two planes) is referred to as the centre of pressure of the biplane system.

Now, as has already been pointed out, the centre of pressure (C.P.) moves to and fro as the incidence changes. If, owing to some disturbance, the incidence is increased temporarily, the C.P. moves forward and introduces a resultant moment which tends to turn the aeroplane in a direction which still further increases the incidence by depressing the tail. Similarly if the incidence is momentarily reduced, the travel of the C.P. backwards introduces a moment about the C.G. which tends to reduce the incidence still further and make the aeroplane dive. If nothing were done about it, the aeroplane would be **unstable.**

A body in equilibrium, and acted on by forces which, if it is disturbed slightly, tend to bring it back to its original position is said to be in **"stable equilibrium"**. If the condition of the body is such that any change in its position, however slight, causes the forces acting on it to increase the movement until some new and entirely different position of equilibrium is reached, the body is then said to be in **"unstable equilibrium".**

To overcome the unstable action of the C.P. movement and to give the aeroplane stability, is the function of the tailplane, a small subsidiary aerofoil placed some distance behind the C.G. of the aeroplane. If this is set so that normally it has no lift, it will, when the C.P. moves forward with increase in incidence, acquire some incidence itself, and so give rise to a vertical lifting force behind the C.G. that will tend to right the aeroplane by calling into play a moment greater than, and acting in the opposite direction to the moment caused by the movement of the C.P. forward.

Similarly as the C.P. moves backward with decreasing incidence calling into play a nose diving movement, the tailplane acquires negative incidence and a downward or negative lift force which tends to raise the nose of the aeroplane, overcoming the instability.

With such a tailplane the aeroplane is said to be **inherently stable** longitudinally.

Before proceeding to the question of lateral or rolling stability, we will define the axes and planes of reference used in the theory of flight.

The fixed axes of an aeroplane are as follows:—

(1) **The longitudinal axis:** is a straight line through the centre of gravity, measured fore and aft and lying in the plane of symmetry. In general this may be taken as being parallel to the axis of rotation of the airscrew. An angular motion about the longitudinal axis is called **"rolling".** The **plane** of **symmetry** mentioned above is that vertical plane which cuts the aeroplane fore and aft into two parts such that each is a mirror image of the other.

(2) **The normal axis:** is a straight line, through the centre of gravity and in the plane of symmetry, at right angles to the longitudinal axis. Angular motion about the normal axis is called **"yawing".**

(3) **The lateral axis:** is a straight line through the centre of gravity and at right angles to the plane of symmetry. It may be taken as being parallel to the line joining the wing tips. Viewed from the pilot's seat,

the positive branch of this axis is to starboard (i.e. to the right). An angular motion about the lateral axis of an aeroplane is termed **"pitching"**.

When the longitudinal and lateral axes are horizontal, the normal axis is vertical. A complete revolution about the lateral axis is called a loop. The plane of symmetry is often referred to as the **looping plane** or the **pitching plane.**

Axes that change direction with change of attitude of the aircraft are:—

(1) **The drag axis:** a straight line through the C.G. parallel to the direction of the relative airflow.

(2) **The lift axis:** a straight line through the C.G. perpendicular to the relative air flow and lying in the plane of symmetry.

(3) **The cross wind axis:** a straight line through the C.G. at right angles to the lift and drag axes.

Planes of Reference: The motions of an aeroplane are referred to three planes fixed with reference to the aeroplane and not to the ground.

(1) **The yawing plane**, perpendicular to the normal axis, in which the longitudinal and lateral axes lie.

(2) **The looping plane,** already mentioned, perpendicular to the lateral axis, in which the normal and longitudinal axes lie.

(3) **The rolling plane,** perpendicular to the longitudinal axis, in which the lateral and normal axes lie.

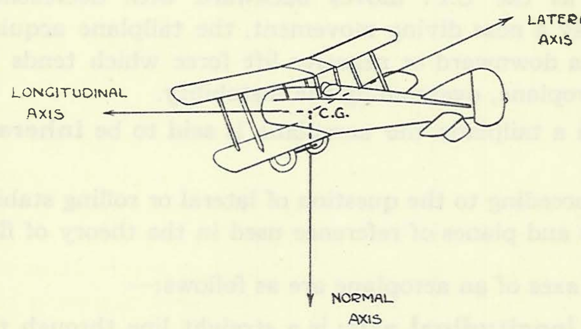


FIG. 13

Fig. 13 shows the three fixed axes.

So far we have briefly considered only equilibrium and stability in the fore and aft or longitudinal direction which is concerned only with stability in the looping plane. **Lateral stability** deals with the stability of the aeroplane in the rolling and yawing planes.

The fin and rudder are vertically disposed aerofoil surfaces which provide stability in the yawing plane, often spoken of as **directional stability.** If for any reason the nose of an aeroplane in flight is disturbed to the right the aeroplane will move in a crabwise fashion and is said to be yawing. The fin and rudder are deflected by the yawing so that they are at a small angle of incidence to the air stream. A side lift, acting to the

right is thereby created at the tail which constitutes a yawing moment tending to turn the nose of the aeroplane to the left, restoring it to its original position. Similarly if the nose swings to the left the rudder and fin experience a cross wind force in the other direction, providing a yawing moment which restores the aeroplane to its original direction. With such an arrangement the aeroplane is said to be directionally stable.

In actual practice as soon as the aeroplane commences to yaw, side pressure is created on nearly every component of the aeroplane, fuselage, undercarriage, struts, etc., all of which then contribute to the resultant yawing moment. The fin and rudder and after end of the fuselage contribute most because they are farthest from the C.G., and therefore exercise more turning effect. The sum of all those areas on the aircraft which give rise to side pressure when the aircraft yaws is known as the "**keel surface**". Normally it amounts to the projected area of the components of the aircraft shown in side elevation, including the airscrew and the projected area of the main planes due to dihedral. If the centre of keel surface is well behind the centre of gravity the aeroplane will possess directional stability.

Sideslip. When an aeroplane in level flight is yawed, it is then moving along the lateral axis as well as the longitudinal axis. When an aeroplane has a component of velocity along the lateral axis it is said to be **sideslipping**. Yawing and sideslipping are then mutually bound together. Yawing means rotation about the normal axis, which always produces sideslip.

Sideslipping is often called **skidding.**

Having considered stability in the yawing plane as part of lateral stability, we finally come to a consideration of stability in the **rolling-plane.**

If an aeroplane is flying normally at an angle of incidence less than the critical angle or angle of maximum lift, its wings are stable in roll, that is to say, if a small disturbance generates a roll, an opposing moment is immediately called into play. Due to its downward motion combined with forward velocity, the falling wing is at a greater angle of incidence while the rising wing is at a lesser angle of incidence than in level flight. Hence the falling wing has greater lift and the rising wing has lesser lift, which explains the existence of the moment opposing the roll. This stability in roll is present only as long as the stalling incidence is not exceeded in which case a disturbance in roll results in the phenomenon of spinning.

Rolling Stability in Sideslip. Suppose, through some disturbance, an aeroplane is flying with one wing down. Gravity will then cause the aeroplane to sideslip towards the lower wing and it is obviously a necessary condition for stability that a restoring rolling moment shall be called into play to lift the lower wing.

This type of stability is achieved by the use of the **dihedral angle** mentioned earlier.

When an aeroplane is sideslipping, the effect of the dihedral angle is, obviously, to give the wing towards which the aeroplane is sideslipping

an **increased** incidence and to give the other wing a **reduced** incidence. In simple language dihedral encourages the airstream to get under the leading wing, and prevents it getting under the following wing. Hence a greater lift is experienced by the wing which is leading in the sideslip than is on the following wing. A rolling moment is thus called into play which lifts the lowered wing tip, restoring the aeroplane to a level keel.

Spiral Stability. It is very necessary in an aeroplane to correctly proportion the dihedral with regard to the size of fin and rudder. Too large a fin and rudder may lead to what is known as spiral instability. Suppose an aeroplane suffers a disturbance which gives it a rotation in yaw. The outer wing is then travelling faster than the inner and consequently has a greater lift, so that a rolling moment is generated tending to roll the aeroplane in the direction of the turn. The aeroplane thus acquires an angle of bank and sideslips inwards. The dihedral angle then comes into operation and tries to lift the inner wing, but the action on the fin and rudder of the side wind due to sideslip calls into play a moment tending to force the nose of the aeroplane into the side wind, i.e., a moment tending to increase the rate of turn. If then the directional stability is so great that the effect of the fin and rudder is more powerful than that of the dihedral angle, the rate of turn will increase and hence the increased velocity of the outer wing tip will increase the roll, the roll will increase the turn still further and so on. Due to the bank the aircraft will be losing height and will be descending in a spiral path of decreasing radius. This instability is known as spiral instability.

RÉSUMÉ OF THE CLASSES OF STABILITY CONSIDERED

Type of Stability	In what plane it applies	Controlling factors
(1) Longitudinal stability	Looping plane	The tailplane
(2) Lateral stability		
A	The yawing plane.	The fin and rudder.
B	The rolling plane.	(1) Stability of wings in roll. (2) Dihedral angle.
C	Combined motion in both yawing and rolling planes. (Spiral Stability)	Correct proportioning of dihedral, fin and rudder.

RECAPITULATION OF THE CONDITIONS FOR FORE AND AFT EQUILIBRIUM OF AN AIRCRAFT

The fore and aft equilibrium of an aircraft depends on the mutual balance of four main forces which act upon it. These forces are:

Thrust, which is the force propelling the aircraft through the air. It is supplied by the airscrew and is shown in the accompanying diagrams as a forwardly directed arrow (see also page 24).

Drag, which is the force set up by the resistance of the air to the forward motion of the aircraft. It acts approximately in an opposite direction to that of the thrust, and is represented in our diagrams by a rearwardly directed arrow.

Lift, which is the upward force on the aircraft, derived mainly from the wings and due to their forward motion through the air.

Weight, which is the force acting vertically downwards through the centre of gravity of the aircraft.

The lift always acts at right angles to the flight path, so that in horizontal flight the lift is vertically upwards, but in a climb or glide the line of action of the lift is inclined to the vertical. The weight always acts vertically downwards whatever the attitude of flight path of the aircraft. The thrust and drag act approximately along the flight path so that in level flight these forces are horizontal.

For the simple case of horizontal flight (equilibrium in climbing and gliding flight is deferred until the next lesson), the four forces enumerated above must balance one another, for the aeroplane to be in equilibrium (see pages 11, 12, and 26). The forward thrust and rearwardly acting drag must be equal and the upward lift and the downward weight must be equal, in order that the four forces will balance one another. Any change in one of these forces will cause the aeroplane to depart from its equilibrium and will cause it to seek a new speed or attitude of flight at which balance will once more be restored. For example, opening of the throttle by the pilot will give rise to an increased thrust which will cause the aircraft to accelerate and hence the drag will increase until a certain higher speed is reached at which the drag will equal the greater thrust.

Increasing the angle of attack of the wings, by depressing the tail, will give rise to an increased lift, more than enough to balance the weight, so that the aircraft will commence to ascend and follow a climbing path.

In the simplest possible case the four forces can all be considered to act through the centre of gravity (C.G.) as shown in figure 13a, and since none of the forces are exerting turning moments on the aircraft about the centre of gravity, the only condition for equilibrium is that the thrust and drag are equal and the lift and weight are equal. This simple case is not

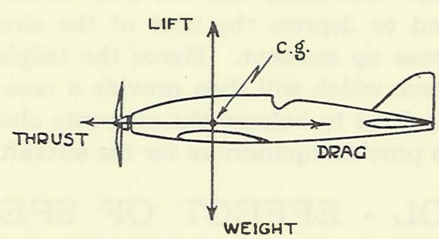


FIG. 13a.

typical of actual practice however, the lines of thrust and drag rarely coincide, and the line of action of the lift constantly changes to and fro as the incidence of the wings is changed and does not therefore coincide with the line of action of the weight (see page 17, centre of pressure).

For equilibrium in horizontal flight under such actual conditions the four forces themselves must still balance, the lift equalling the weight and the thrust equalling the drag, but our second condition of equilibrium must also be fulfilled, that is, the turning moments of each of these forces must balance among themselves (see pages 11, 12, and 26). This would not always be possible without the presence of the tailplane which provides a small vertical force at a great leverage arm from the centre of gravity. By adjusting the tailplane the pilot is enabled to change this lift on the tailplane so that a moment about the centre of gravity can be provided which will balance the aeroplane in those cases where the moments of the thrust, drag and lift about the centre of gravity will not balance out among themselves alone (see page 27).

Fig. 13b shows an example in which the thrust line is above the line of drag. Other types of aeroplanes can be cited in which the thrust line is below the drag line. The lift is shown acting behind the centre of gravity, corresponding to the high speed condition of level flight (had the lift been

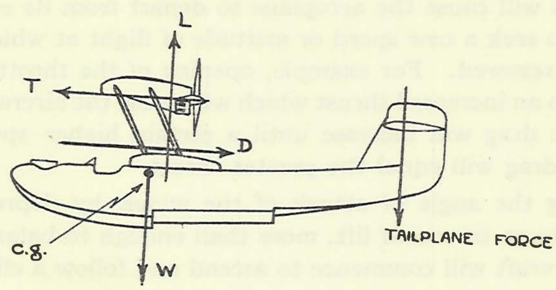


FIG. 13b.

ahead of the C.G., it would have corresponded to the case of an aircraft flying at low speed). Obviously the lift and thrust are both exerting moments which tend to depress the nose of the aircraft. The drag is providing a small nose up moment. Hence the tailplane must be set to give a downward force which will then provide a nose up moment about the C.G., sufficiently large to balance the moments about the C.G. due to T, L, and D, and so provide equilibrium for the aircraft.

CONTROL - EFFECT OF SPEED ON EQUILIBRIUM - GLIDING - TURNING

Lesson No. 4

CONTROL

The control of the aeroplane longitudinally (in the looping plane) is effected by use of the elevators. The elevators are control surfaces hinged to and forming a prolongation of the tailplane. The tailplane and elevators considered as one unit, form an aerofoil. The elevators can be moved through an arc about their hinges and their action is such that in

effect the camber of the tailplane elevator combination is varied through a certain range. Suppose that the tailplane and elevators are so set as to give no component force perpendicular to their chord line, and that the elevators are depressed independently of the tailplane. A virtual camber and incidence is then given to the tailplane elevator combination, which deflects the air flow and gives a reaction on the tailplane elevator combination at right angles to its chord. This force constitutes a pitching moment about the centre of gravity, which rotates the aeroplane about the lateral axis. Thus the pitching of the aeroplane is under control of the pilot as he moves his elevators.

By raising the elevators, the aeroplane is rotated in pitch so that the angle of incidence of the wings is increased. This results in more lift on the wings and the aeroplane climbs along an ascending path.

The rudder controls the aeroplane in the yawing plane. The rudder is, therefore, the **directional control.**

The rudder in conjunction with the fixed fin acts as a variable camber aerofoil whose surface is at right angles to that of the tailplane and elevator. The reaction forces set up by operation of the rudder constitute yawing moments about the centre of gravity, which rotate the aeroplane about the normal axis.

The ailerons provide control in the rolling plane, i.e. control about the longitudinal axis. On either wing tip, they form the trailing portion of the wing in front of them. They are hinged about their leading edges and can be rotated through an arc by the pilot. They move always in opposite senses, as one goes up the other depresses. The effect of moving them is to change the effective camber and incidence of those parts of the wing to which they are attached. This gives an increased lift on one wing and a decreased lift on the other, in other words, a rolling moment is called into play which causes the aeroplane to bank.

A secondary effect of this unequal lift on the wings is a tendency for the aeroplane to yaw about the normal axis. The wing which has the depressed aileron and hence the greater lift also has a greater drag (due to the larger camber and incidence) while the drag of the wing with the raised aileron is reduced.

This yawing tendency is known as "**aileron drag**" and can easily be corrected by the rudder.

Control at the Stall. Consider what happens to an aeroplane at the stalling incidence, say at the moment of landing. If one wing drops and the pilot tries to lift it by depressing the aileron on that side in the normal way, he virtually increases the camber and incidence of that wing. Now as the wings are already **at** the stalling angle, the action of the pilot causes the depressed wing to **exceed** the stalling angle and a loss of lift will result which may cause the wing to drop still further. The increased drag on the depressed wing (due to aileron drag) will cause a yawing so that the depressed wing travels more slowly and the raised wing travels more rapidly. This difference in speeds results in less lift on the depressed wing and more lift on the raised wing which still further aggravates the condition.

Thus the use of the aileron at an airspeed near the stalling speed may produce a reverse effect to that produced in normal flight and may cause loss of control. This question is of great importance when landing an aeroplane in a high gusty wind, especially if the aeroplane happens to be slightly out of wind.

Balanced Controls. All control surfaces may be partly balanced so that the force to be exerted by the pilot in operating them is reduced considerably as compared with unbalanced controls. Balancing the controls is essential on large aeroplanes.

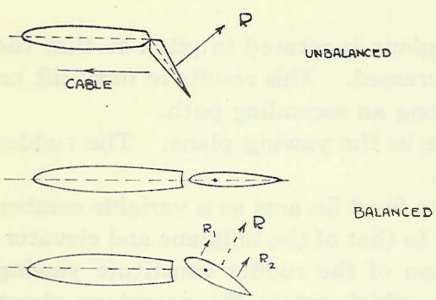


FIG. 14

Consider a control surface depressed as in Fig. 14. Then the resultant air force R on the surface tends to rotate it upwards about the hinge, and the surface can only be kept in position by the pilot exerting a force on the control column such that the moment, about the hinge, of the tension in the control cables just balances the moment of R about the hinge, called the **hinge moment.**

In a balanced control a portion of the control surface lies in front of the hinge line, so that the moment of the air forces on the front part helps to relieve the pilot (see Fig. 14). In other words the hinge is placed nearer to the resultant air force R on the control surface, so that the hinge moment is reduced. The surfaces are never completely balanced (hinge moment zero), otherwise the controls would be robbed of their **feel.**

Fig. 15a shows various types of balanced controls.

Fig. 15b shows the sections of three widely used types of balance.

(I) is the well known inset balance.

(II) is the "paddle" type balance in which area is provided ahead of the hinge line by the use of an auxiliary surface mounted on arms attached to the main surface.

(III) is the Frise balance — the most satisfactory form for ailerons. When the aileron is up, the leading edge projects below the wing and thereby adds a drag to the wing which tends to counteract the yawing moment due to aileron drag, (in which the up aileron has reduced drag and the lowered aileron increased drag).

Effect of Speed on Equilibrium in Level Flight. If the engine of an aeroplane in level flight is opened up, due to the extra power it will accelerate and fly more rapidly. If the incidence of the wings is unchanged, due to the extra speed there will be a greater lift on the wings and the aeroplane will climb. For level flight to be maintained the pilot will have **to** ease the control column forward to reduce the incidence until the lift again just balances the weight (the lift is then the same as before but is obtained by the use of **higher** speed at **smaller** incidence).

When an aeroplane is in flight and the speed is varied a number of pitching moments are called into play. These arise from the following sources:—

(1) Movement of the C. of P. of the wings backward as incidence is reduced (speed increased).

(2) If the C.G. is not on the airscrew axis, a moment will be present due to the thrust, tending to rotate the aeroplane about the C.G. This moment will vary as the thrust varies.

(3) The effect of the slipstream on the tailplane. If the velocity of the slipstream increases due to increased speed of the aeroplane the reaction on the tailplane will be augmented and hence a changed moment about the C.G. will result.

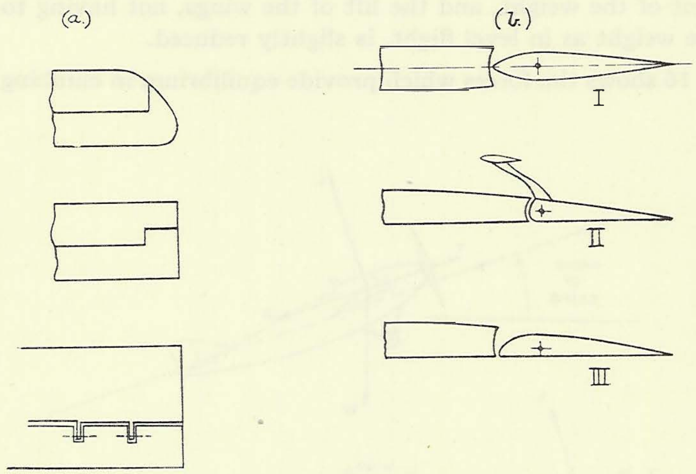


FIG. 15

In order that the aeroplane may be in equilibrium there must be no resultant moment acting on it, so that for all speeds of forward flight the pilot must adjust the elevator to provide a balancing moment. This becomes tiresome during a long flight and for this reason the **tail adjusting gear** is provided. This is a mechanism which allows the pilot to alter slightly the angle of incidence of the whole tailplane so that instead of holding the elevators to provide a balancing moment, he can change the incidence of the tailplane leaving no load to be carried by the control column. The process of thus adjusting the tailplane is called **"trimming"** and when the equilibrium of the aeroplane has been so adjusted it is said to be **in trim** because its forces and moments balance without the pilot having to apply any manual correcting moment with the control column. Clearly from the three above mentioned sources of pitching moments, one particular tailplane setting will only trim the aeroplane in one given condition of flight. In other words if the speed of flight is changed the tailplane must be readjusted to some new position in order to put the aeroplane once more in trim.

Particularly is this change in trim noticeable when the engine is throttled back. The absence of the powerful slipstream on the tailplane makes it necessary to either pull back on the control column or else reduce the tailplane incidence with the tail adjuster to trim the aeroplane for gliding without engine.

Climbing Flight. The angle of climb is limited by the power available from the engine. When the aeroplane is climbing, the engine, in addition to overcoming drag, has to do work in lifting the aeroplane against the opposing force of gravity, and this rate of lifting is limited by the extra power available. When climbing at a constant speed the aeroplane is in equilibrium, and if the angle of climb is small the lift required from the wings is approximately the same as in level flight. If, however, the angle of climb is very steep, the airscrew thrust is supporting an appreciable component of the weight, and the lift of the wings, not having to support the entire weight as in level flight, is slightly reduced.

Fig. 16 shows the forces which provide equilibrium in climbing flight.

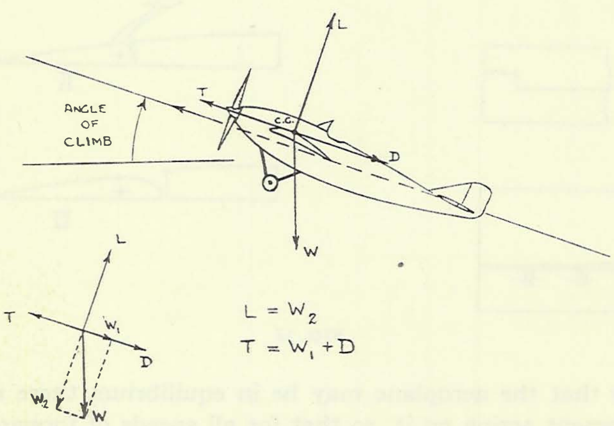


FIG. 16

Gliding Flight. In level flight the engine provides the power required to overcome the drag of the aeroplane. If the engine is stopped, the flight path must be changed so that the weight of the aeroplane has a component in the direction of flight (See Fig. 17), gravity then providing the necessary power. The aeroplane is then said to be **"gliding"** and the angle that the flight path makes with the horizontal is known as the **"gliding angle".**

Whilst gliding without engine two forces only are acting on the aeroplane, the weight acting downwards and the resultant air reaction which, for equilibrium, must therefore be acting vertically upwards through the C.G. (See Fig. 17). This condition is automatically arrived at when the pilot adjusts the glide.

The weight and total air reaction can be resolved into two components at right angles. One along the flight path and the other at right angles to it. The air reaction is resolved into a lift and drag. The drag acting in the line of flight is then balanced by that component of the weight acting in the line of flight. The lift is balanced by the other component of the weight.

Since the weight is balanced by the whole air reaction instead of just one component of it, the "lift" required is actually less than in level flight.

By the geometry of Fig. 17, it can be seen that the angle *LOR* is equal to the gliding angle. Now we have already seen that a small value for the angle *LOR* corresponds to a high *L/D* ratio, so that in order to have a small gliding angle the aeroplane must have a high *L/D* ratio, and must be flown at such a speed and incidence that the *L/D* ratio is at its maximum value.

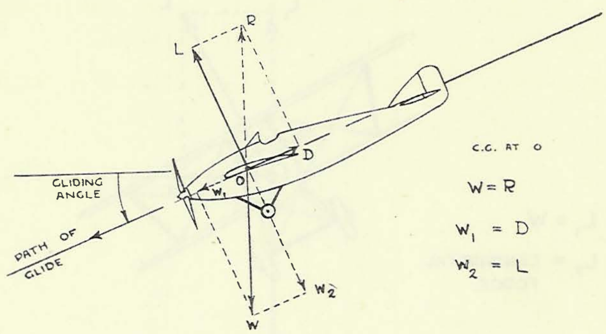


FIG. 17

The gliding angle corresponding to this maximum *L/D* ratio is called the **best gliding angle** for the particular aeroplane considered.

At the best gliding angle the aeroplane will travel farthest for a given loss of height, thus giving the largest choice of a landing point in the event of engine or fuel failure.

If the angle of glide exceeds the best gliding angle, the aeroplane will dive more steeply to the ground. If the angle is less than the best gliding angle the incidence will have to be near the stalling incidence to provide enough lift, and the aeroplane will **"pancake"** to earth.

Turning. When an aeroplane is turning uniformly, a constant force must be exerted on it, acting inwards towards the centre of the turn, in order to force it to maintain the turn, otherwise the aeroplane would continue in a straight line. The aeroplane is in equilibrium whilst turning so this inwardly directed force must be balanced by an equal and opposite i.e. outwardly directed reaction. This outward force which has already been referred to is called the centrifugal force.

The inwardly directed force is known as the **centripetal force.** The centripetal force in a turn is provided by the wings. In order for the wings to do this the aeroplane must be banked so that the lift on the wings is inclined inwards from the vertical. The horizontal component of the

lift is then the centripetal force which balances the centrifugal force, and the vertical component of the lift balances the weight. Fig. 18 gives a diagram of the forces.

Since the weight is balanced only by a **component** of the lift, the lift in a turn has to be greater than in normal level flight, the wings have therefore to be put at a greater angle of incidence.

The steeper the angle of bank, the smaller does the vertical component of the lift become and hence the larger the lift must be if the vertical component is still to balance the weight and prevent the aeroplane from losing height in the turn. The speed may still remain approximately the same as in level flight yet the wing incidence must be increased considerably if the turn is a **"steep turn"**.

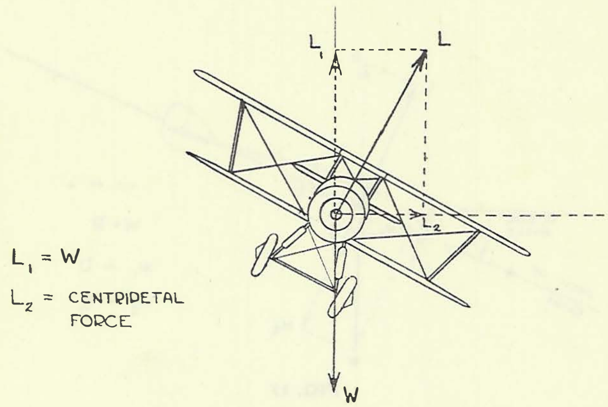


FIG. 18

If at a given speed the turn is made too steep, the incidence may rise as high as the stalling incidence and the aeroplane may stall in the turn even though the speed is much higher than the normal level flight stalling speed. Similarly, if the turn is only a moderate one, and the speed is allowed to decrease, the lift falls below the required lift (which due to the turn is greater than the lift required in level flight) long before the normal stalling speed is reached. In other words, when an aeroplane is turning, the stalling speed is higher than normal, depending on the steepness of the turn. The steeper the turn, the higher is the stalling speed.

For a typical case:—

Angle of bank	Stalling speed
0°	45 mph
30°	49 mph
50°	58 mph
60°	65 mph
70°	80 mph

The steeper the turn, the greater is the horizontal component of the lift, i.e., the centripetal force is larger. The centripetal force governs the rate of turn so that in a steep turn the **rate** of turn is much increased and the aeroplane turns rapidly on a short radius.

Loading in a Turn. Since the lift force (*L* in fig. 18) is much greater in a turn than in normal flight, the loads in a turning aeroplane are greater than in level flight. The ratio of the loads in the turn to the loads in level flight is obviously equal to

$$\frac{\text{lift in the turn}}{\text{lift in level flight}} = \frac{\text{lift in the turn}}{\text{weight}}$$

This ratio is called the **load factor**. The load factor increases rapidly with the angle of bank, thus:—

Angle of bank	Load factor
0°	1
35°	1¼
50°	1½
60°	2
70°	2.8
80°	5½

These figures assume that the speed of flight is unaltered. In practice the speed is reduced to keep these severe loads down. The pilot's weight increases in the ratio of the load factor and this gives him an indication of the loading to which he is subjecting the aeroplane.

In a **gliding turn** more lift must be provided than in a straight glide and hence a steeper angle of glide must be used. Great care must be taken to avoid stalling by overloading because a steep gliding turn means a heavy loading and demands more speed, which necessitates a steeper gliding angle.

In a normal turn at a given angle of incidence the aeroplane tends to overbank due to greater lift on the outer wing tip, which of course is travelling faster than the inner wing tip. This tendency is checked by the pilot. In a gliding turn, however, this tendency is absent because the aeroplane is descending in a spiral and the inner wing is describing a steeper spiral than the outer wing and thus meets the air at a greater angle of incidence. The extra incidence of the inner wing compensates for the extra speed of the outer wing and no overbanking tendency is present.

Power Required in a Turn. At a given speed of flight, greater power is required in a turn than in level flight, because in the turn greater lift is required which requires a greater incidence, and hence greater drag arises due to the larger incidence. An aeroplane can only maintain height whilst turning continuously by reason of the excess power available over that required in level flight at the same speed. Since the engine power is limited it is readily understood why an aeroplane will stall on a steeply banked continuous turn.

Climbing turns. In a climbing turn the engine has to provide extra power to do work in lifting the aeroplane away from the ground in addition to extra power needed for turning. For this reason the angle of climb must be kept **below** the best climbing angle, and the angle of bank in the turn must be **very** gentle. This is particularly important on low powered

aircraft. Due to the ascending spiral path there is a greater tendency to overbank in a climbing turn than in a level turn. The inner wing ascends on a steeper spiral and therefore has less incidence than the outer wing.

AEROBATICS AND SOME PRACTICAL CONSIDERATIONS

Lesson No. 5

Aerobatics. The essential nature of all aerobatics is such that the aeroplane is performing manoeuvres in which the speed, attitude and direction of flight are continually changing. Heavy loads, especially lift loads are required to make the aeroplane change its attitude and direction of flight in such short spaces of time. These loads are usually secured by first increasing the speed of flight by a slight dive. The loads on an aeroplane are among other things proportional to the square of the speed so that a very slight excess of speed over level flight speed can result in appreciable extra loading.

In view of the heavy loading, aerobatics should only be performed in an aeroplane which has definitely been designed to do aerobatics, to ensure a sufficient margin of strength. An inexperienced aerobatic pilot attempting aerobatics can, through misuse of the controls, cause much heavier loads on the aeroplane than those which an experienced pilot calls into play in doing the same manoeuvre.

The severest loading in nearly all aerobatics occurs when the pilot attempts to rapidly increase the angle of incidence when flying at high speed. Such cases are typified by:—

(1) When the entry into a loop is executed, the aeroplane having been dived to gain speed is then pulled up to a greater incidence to obtain the lift necessary to execute the vertical turn or loop.

(2) In a flick roll in which the wings are pulled up to the stalling incidence whilst the aeroplane is flying along at normal flight speed.

(3) A vertically banked turn in which the incidence and speed are both as high as possible to provide the necessary centripetal force for the execution of the turn.

Spinning. A spin is not only a manoeuvre that can be definitely performed by the pilot, but it is also a condition of flight in which the aeroplane may be stable as well as in equilibrium.

Consider an aeroplane wing at or near the stall and suppose one wing is dropped either accidentally or due to use of the rudder. Due to its motion downwards as well as forwards, the falling wing will be at a greater angle of incidence and the rising wing at a lesser angle of incidence than previously. This may be sufficient to cause the falling wing to exceed the stalling angle so that it is completely stalled whilst the rising wing will be unstalled.

The lift will then be less on the falling wing and greater on the rising wing, in other words, a rolling moment is introduced tending to keep the

wings rotating. This phenomenon is called **autorotation.** The wings are **unstable** in roll. (We have previously shown how below the critical angle all wings are **stable** in roll).

The effect of this property on an aeroplane which is stalled and then given a disturbance in roll or yaw is to cause the nose to drop and autorotation to set in, and the aeroplane starts a spinning nose dive or spin.

The motion is actually a combination of rotation about all the axes and the aeroplane descends rapidly in a steep helical path. The rate of descent varies with the type but is normally between 50 and 75 m.p.h. The angle of incidence varies over the span of the wings but the average may rise to very high values especially in a **flat** spin when it may be as high as 80°. In a normal spin it may be as high as 30°, so that the wings are well stalled.

Checking the turning of the aeroplane by use of the rudder and unstalling it by easing the control column forward is the correct procedure for recovery.

An accidental spin is often aggravated by aileron drag. Powerful rudder control and Frise type ailerons reduce the dangers of an accidental spin occurring.

Interconnected Slot and Ailerons. The slot is a small auxiliary wing which fits on the leading edge of the main wing. It can be opened up either manually or automatically (by the action of the air forces on it) to leave a gap between itself and the main wing. The effect of the slot is

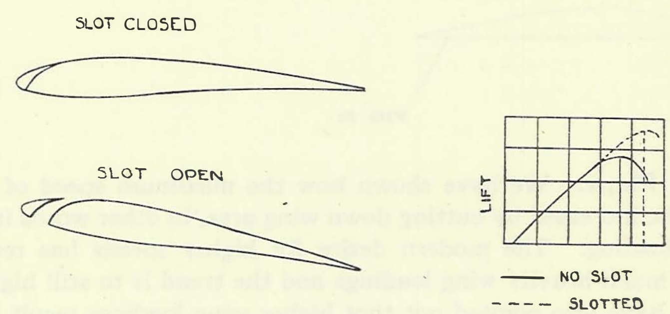


FIG. 19

to increase the critical or stalling angle and also to increase the maximum lift that can be obtained. The slot itself will be treated in more detail later on.

When the slot and aileron are interconnected so that the amount of slot opening varies with the aileron movement, then, normally closed, the slot is opened when the aileron is depressed. An accidental falling of one wing can be corrected by aileron without fear of stalling the wing because the opening of the slot delays the critical angle. Lateral control is improved and aileron yawing moment is reduced and the chances of an involuntary spin very much minimized.

The Automatic Slot. Fig. 19 shows the slot both closed and open. By suitably choosing the shape of the auxiliary aerofoil or slot and the links on which it moves, it is possible to make the slot open automatically under the action of the air forces at an angle just below the normal stalling angle. When this occurs the wing continues to lift to an incidence considerably greater than the original stalling incidence, thus increasing both maximum lift and stalling angle.

The shape of the gap between the main and auxiliary wings is important. In our discussion of stalling we showed that it was due to piling up of dead air and eddies on the top surface of the wing. The slot induces a jet of high velocity air to flow through it which sweeps away the dead air and eddies, the air flow again conforms to the upper surface contour and the wing continues to lift to a greater angle of incidence.

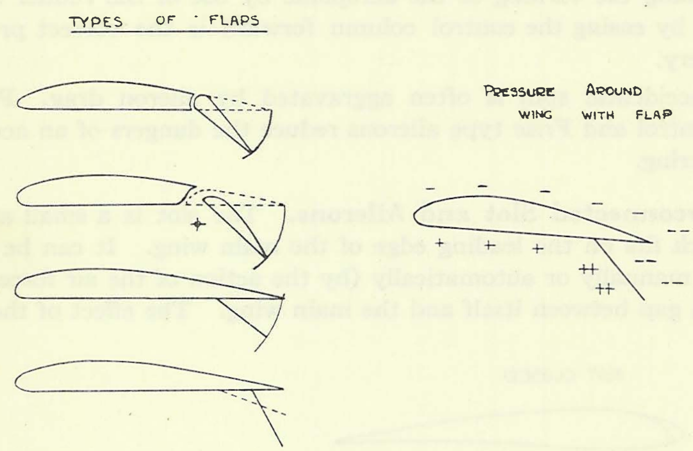


FIG. 20

Wing Flaps. We have shown how the maximum speed of an aeroplane can be increased by cutting down wing area, in other words increasing the wing loading. The modern desire for higher speeds has resulted in the use of much heavier wing loadings and the trend is to still higher loadings. We have also pointed out that higher wing loadings result in higher landing speeds.

The desire for high speed has also resulted in great cleanliness of design, aeroplanes being so carefully **faired** or steamlined that their drag is as small as possible.

We also pointed out that low drag results in a nice small gliding angle.

This combination of high landing speed and small gliding angle has rendered it very difficult to land some modern aeroplanes on small aerodromes surrounded by tall obstacles. Devices are required which can be used in landing to (1) increase the maximum lift coefficient which will then reduce the landing speed (as mentioned earlier), (2) steepen the gliding angle by increasing the drag of the aeroplane.

The automatic slot is a useful device because it increases the maximum lift coefficient but the **wing flap** does both. There are several kinds of wing flap but in essence they consist of a hinged flap or surface near the trailing edge of the wing which normally lies flat but can be lowered about the hinges at its front edge. (See Fig. 20).

The action of the flap is obviously to increase the drag. The lift is also increased because behind the bluff flap is a region of negative pressure or suction which has the effect of lowering the level of suction over the whole region above the wing. This increased suction over the wing results in increased lift.

The suction behind the flap together with the pressure on the front of it, is of course responsible for the increased drag.

PRACTICAL CONSIDERATIONS

Taking Off and Landing Into Wind, as Against Down Wind. Since it is speed relative to the air and not to the ground that is important, flying speed is gained and lost at a **much** lower ground speed when the aeroplane is facing into wind than when facing down wind. This is advantageous for the following reasons:

(1) Taxying shocks and stresses are reduced, due to low ground speeds and greater wing lift at those ground speeds.

(2) Take off run and landing run are materially reduced.

(3) Angle of climb in taking off and angle of descent in landing are very much steeper which minimizes the danger of collision with obstructions round the aerodrome.

Landing. The landing at slowest possible ground speed can be made by using the engine, in which case a component of thrust helps to support the weight and reduces the lift required from the wings. The technique, however, is difficult to master for a pilot who is not very experienced. If the landing is to be made without engine the slowest possible landing is that which is effected by gliding in normally at best gliding angle, flattening out (changing the inclined gliding path to a path parallel to the ground) when nearing the ground, and stalling the aeroplane when the wheels and tail skid are about 1 foot off the ground. A fallacious belief is often noted that pancaking the aeroplane or dropping it from a height gives a slow landing. A study of the effect of stalling an aeroplane at a safe height will quickly disprove this belief.

As soon as an aeroplane is stalled the nose drops and it **gathers** speed.

Landing in a High Wind. In landing in a high wind it is very important to land directly into wind, otherwise, the wind will blow the aeroplane sideways (drift) and may damage the undercarriage. If drift is noticed at the last minute it can be corrected by sideslipping into wind. It is better to undercorrect drift than to overcorrect it, since the resulting loads on the undercarriage are more safely taken with undercorrected than overcorrected drift.

Another danger in drift is that once on the ground, the wind may get under the near wing and blow the aircraft over sideways. It is better to turn **down** wind than up wind after landing, for two reasons. Firstly the loads on the undercarriage during turning will be less when turning down wind than when turning up wind and secondly due to the incidence of the wings when on the ground, turning up wind encourages the wind to get under the inner wing tip, whilst turning down wind causes the wind to assist in holding the wings down thus reducing the tendency to blow over.

In landing in a high wind it is better to glide in with greater speed than usual because in a high wind, gusts or **bumps** are present near the ground and the aeroplane may suddenly fly into a gust relative to which its speed is **less** than the stalling speed, even though relative to the general or average wind it may be greater than stalling speed. The aeroplane suddenly entering such a gust loses its lift, drops very suddenly and violently and may damage its undercarriage. A little engine or excess gliding speed will prevent such an occurrence.

Flying Near the Ground. In flying near the ground, especially in a strong wind, great care must be exercised. Turning an aeroplane in a strong wind of **uniform** velocity is exactly the same as turning in still air; a turn executed from a direction into wind to one facing down wind presents no differences to a turn in still air, for although the ground speed of the aeroplane goes through some considerable changes, the **relative** velocity with respect to the air is the only thing that is important to the aeroplane and this is independent of the wind. The proximity of the ground, however, introduces a number of features.

Turns executed near the ground can be hazardous especially in a wind. We will consider the worst case, that is of a pilot who attempts to turn down wind just after taking off. This is a particularly dangerous manoeuvre for the following reasons:—

(1) The aeroplane will not have gained much speed and may, therefore, stall on the turn, especially the inner wing on the turn, which will be travelling slower than the outer.

(2) Even if sufficient speed has been obtained for safe level flight, we have already seen that stalling speed is higher in a turn than in level flight, consequently there is but a small margin of speed.

(3) Proximity of the ground can upset the pilot's judgment, especially the effect of the wind on his track over the ground, which may mislead him.

(4) The presence of gusts of varying force and **direction** near the ground in a high wind which may result in the aeroplane losing flying speed relative to a particular gust which it may meet, resulting in a stall. The gust effect of course is aggravated by the higher stalling speed on the turn and the probability that the aeroplane has only just achieved a small margin of flying speed after take-off.

(5) The proximity of the ground leaves no height margin to correct an emergency, loss of height in the turn due to any of the above causes leading almost certainly to disaster.

The gust effect mentioned in (4) can be elaborated profitably. Suppose an aeroplane which stalls at 40 m.p.h. is flying into a wind of 20 m.p.h. and suppose that its airspeed is 50 m.p.h. Its ground speed is then 30 m.p.h.

Suppose that it meets a gust or lull whose speed is only 8 m.p.h. in the same direction as the wind. Then relative to the air in this gust the aeroplane will only be flying at 38 m.p.h., and since it stalls at 40 m.p.h. the aeroplane will drop immediately. It is obvious that the gust effect is only really serious at speeds near the stalling speed.

AIRMANSHIP

Treated under the following headings:

I Pilot's inspection, before, during and after flight.

II (a) Care of engines and aircraft.

(b) Aids to cross country flying.

PILOT'S INSPECTION BEFORE, DURING AND AFTER FLIGHT

Lesson No. 1

(I) **Before Flight.**—Constant, never-ending vigilance is the price of safety where any form of rapid transportation is involved. Railway and coach lines carrying passengers give a meticulous daily inspection to their equipment and have in addition scheduled periods of inspection. The aeroplane, the fastest of all the forms of locomotion, by the very nature of the medium through which it moves, needs the most constant and careful inspection. This is particularly true in training schools and clubs where the planes are subjected to heavy usage and are constantly being handed from one pilot to another.

Inspection, to be of use, must be systematic. A systematic inspection has two advantages: (i) it ensures covering all the necessary points of inspection; (ii) it cuts down the time taken for inspection. The following is suggested as a useful method of procedure:—

Before starting the engine see that the engineer has signed the log books and do likewise.

(I) Examine airscrew for: (a) tightness at hub; (b) freedom from flaws.

(II) Engine cowls complete and locking devices secure.

(III) Undercarriage airworthy (a) wheels secure; (b) tires properly inflated.

(IV) Port wing: (a) wing-root locking bolts secure; (b) fabric free from holes or wrinkles, top and bottom; (c) landing and flying wires taut, true to front and locked; (d) interplane struts secure, true to front and unbowed; (e) incidence wires taut and true and locked; (f) move out to wing-tip and rock the whole plane, gently at first, then with increasing vigour, meanwhile watch the compression legs, centre-section cross-bracing wires, etc., to see if any looseness develops, watch the wing fabric too, to see that no undue wrinkles appear; (g) examine the aileron hinge-pins and control connections.

(V) **Fuselage:** (a) examine fabric, especially for wrinkles; (b) feel rudder and elevator cables for tension, fraying, and secure locking.

(VI) **Tail units:** (a) tailplane fabric, top and bottom (the under surface is frequently damaged in taxying over shrubs, stakes, etc.); (b) shake the main spar to see that it is tight.

(VII) **Elevator:** examine hinge bolts for play and secure locking; inspect control locking devices carefully, inside the fuselage and out.

(VIII) **Rudder:** examine hinges and controls as on elevator; see that sternpost is secure and upright and fin secure.

(IX) **Tail skid:** look for cracks, wear, sheared bolts, etc.

(X) examine the starboard side of the fuselage and the starboard wing in the same way as those on the port side.

(XI) feel centre-section cross bracing wires.

(XII) note gas supply.

(XIII) look in front seat to see that it is clear of cushions; belt secure; stick out, etc.

Examination from Pilot's Cockpit

(a) Note the oil pressure. (b) Set the altitude control to zero. (c) Move the elevator, aileron and rudder controls and watch the aerofoils concerned carefully to see that they move in the proper manner and are not unduly loose or tight. If either an unusual looseness or tightness develops, report the matter at once to the air engineer and see that it is investigated. (d) Run up the engine; note the rpm and oil pressure. See that the engine controls are secure and moving freely. (e) Cut the switches one at a time to test the magnetos.

(II) During Flight: (a) Feel the controls and check the aeroplane to see that it has no tendency to fly with one wing low or to fly nose or tail heavy. (b) Note the oil pressure and the rpm and check the magnetos again. (c) Check the readings of the airspeed indicator and altimeter. You cannot do this with precision of course, but it is easy to tell if an instrument is not working or is seriously in error. (d) Note the setting of the incidence gear in climbing and gliding. (e) Note any vibration or unusual noises in the engine.

(III) On the ground after Flight: (a) Check the magnetos again before shutting off the engine. (b) Report any faults that you may have observed to the engineer.

It may be objected that all this takes time. The answer is that, in flying, nothing must be permitted to be done in a rush. The inspection before flight, as outlined above, if systematically carried out takes only a few minutes and is well worth the time it takes. The pilot or student who takes a plane over from another pilot without first giving it a good looking over is asking for trouble since he is certain, sooner or later, to have the results of another's bad landing or other misdemeanour charged to his account.

In this lesson each student must be encouraged to go through the routine of examining the 'plane before flight (with the exception of rocking the 'plane from the wing tip which had best be left to the instructor) under the direction of the instructor who should demonstrate the methods and purpose in each phase of the examination.

As a last measure, the student should be directed to stand out in front of the centre of the 'plane about 50 feet away from it to examine it carefully for symmetry. If the tailplane is not set symmetrically with the main planes, or if one wing appears lower than the other the cause thereof should be investigated. Students should be taught to be on the lookout for wrinkles in the fabric. Wrinkled fabric usually indicates a broken or distorted member inside the fabric.

AIRMANSHIP

Lesson No. 2

(a) CARE OF ENGINES AND AIRCRAFT
(b) AIDS TO CROSS COUNTRY FLYING

(a) **Care of Engines and Aircraft.**

Introduction. The air engineer, particularly the club engineer, is always a busy man. It is a heavy responsibility to supervise all the activities concerning his beloved engine both in hangar and in workshop at all times. **Some** of the responsibility for the care of engines rests on the pilot, and the present tendency to "pass the buck" at all times to the engineer must be discouraged. For his own good the pilot should be taught how to get the best results from his engine.

In the hangar: (i) Care must be taken in running up an engine not to blow dust into the hangar. The valve operating mechanism of aero engines is peculiarly prone to collecting dust and grinding it into the working parts. This turning of the tail into the hangar door and raising a cyclone is a tediously senseless proceeding, yet it happens in every busy aerodrome in Canada every hot day in summer.

(ii) In winter, we spoil the oil after we have drained the crankcase for the night by (a) burning it in heating or (b) letting dust and dirt get into it, or both. In warming an engine in winter it occasionally happens that the primus heater is so placed under the tent that the H.T. wiring has the insulation roasted and swelled to the point where it is unfit to use.

Starting. See that chocks are placed in front of the wheels and that the man swinging the prop has a good secure footing. Get the habit of adhering strictly to the following formula:—

Mechanic: "Gas on. Switches off. Throttle open. Suck in".

Pilot repeats, performing the actions: "Gas on. Switches off. Throttle open".

In calling for "contact" and "switches off" it is essential that the words be shouted out in a good clear voice and that a distinct pause follow each operation. The writer has in mind a case in which, the operation being hurried, the operators failed to synchronize, with unpleasant results. When the engine starts, note the oil pressure. If the gauge fails to register within 20 seconds give the engine a gentle burst and, if there is no

sign of oil pressure, switch off and look for the cause of the trouble. Warm a cold engine for at least 4 minutes before running up. It is good practice to warm an engine till the oil pressure is near normal before running to full throttle. In testing the switches, do not run the engine at full throttle for more than a few seconds as the cooling is not good, and overheating may result.

Before operating a new engine the **pilot** must know:

(I) Minimum and operating oil pressure. (II) Full revolutions on the ground and cruising and maximum revolutions in the air. (III) All about the fuel system, i.e., number and capacity of tanks; position and reading of gauges; position and method of operating the control to each tank line. (IV) The position and operation of the switches; and the operation of the magneto advance and retard mechanism if any. (V) The correct method of reading all engine instruments.

Taxying: Avoid a quick and jerky use of the throttle. Opening and closing the throttle suddenly is hard on the engine and doesn't help in taxying.

In the Air: Climbing. If your book of instructions says, "Cruising revs. 1900 rpm." then it is correct to climb at 1900 revs. even if you need nearly full throttle to do it. Be sure, however, when you lower the nose and take up cruising position, to move back the throttle and keep the revolutions at not more than 1900 rpm. Forgetting to set back the throttle is probably the most frequent cause of engine trouble among beginners.

In the Air: Gliding. Do not jerk the throttle back suddenly when you throttle back to go into a glide. In winter flying it is necessary to give the engine frequent gentle bursts while gliding down from a height in order to keep the engine at operating temperature. If it is permitted to become very cold there is every likelihood of the engine failing to start when the throttle is opened.

It should be pointed out here that the careful pilot will adjust the throttle setting in cruising to that point where the running of the engine is smoothest, i.e., the point of least vibration. It is altogether likely that the engine will develop greatest efficiency with the least wear at this point even if it is a few revs. more or less than required by instructions.

Fuels and Refuelling. There is a great difference in the quality of gasoline fuels in use and aero engines are peculiarly sensitive of these differences. The best gas available for a given type of engine should be ascertained and only that gas should be used. Inferior gases may cause: (i) Loss of power; (ii) Overheating; (iii) Pre-ignition; (iv) Warping of the valves or burning of the valve seats; (v) Sticking valves through the presence of gum or other impurities. Make a point of finding out what grades of gasoline may be safely used in your engine as a temporary substitute for the gas you use at home.

Refuelling. (i) Refuel at night so as to prevent water condensation in your tank. (ii) Filter the gas through a felt strainer so as to keep out

water and solid impurities. (iii) If a funnel is used, take great care that no insect has crawled into the inside of it to plug up your gas line later on. (iv) Never refuel in the open if it is raining as you are likely to let water into the tank. Take care that the funnel is making good metallic contact with the tank as there is danger of a spark, resulting from static electricity, starting fire.

(b) Aids to Cross Country Flying. Since the whole purpose of flying is to move rapidly from one place to another with a minimum of discomfort, it is natural that we should devote some time to this important subject. The notes given below are based on the cumulative experience of a number of pilots gathered through years of experience in flying. If contemplating a cross country flight, give yourself plenty of time to make full preparation. **Don't try to rush things.**

Before starting: Be certain that the aircraft is serviceable and properly signed out in accordance with regulations. See that your aircraft is properly serviced, i.e., that your gas and oil tanks are filled to capacity. Don't assume that this has been done — make certain. If the distance to be covered is beyond the capacity of your tanks, plan your refuelling point with a good margin of safety. 45 minutes should be taken as a minimum reserve. When refuelling, **always** fill up full — the unexpected may happen even to you: it frequently happens to other people. Never rely entirely on your gauges; ascertain your consumption per hour and calculate your fuel reserve from that.

Maps. Secure good air maps of the route to be flown over. If the country is new to you, devote a good slice of your time to studying the route. Note prominent landmarks; rough areas, hills, mountains, etc., and the height you will need to clear them; (it may be possible to fly around intervening heights of land if the ceiling is low. Remember that a 1,000 foot ceiling becomes "no visibility" if the ground rises a thousand feet); the altitude of the 'drome at your destination; the area for some miles around your destination so that you will be certain to recognize the point when you get there, or find your way to the aerodrome in case of poor visibility. Fold your map carefully in such a way that the track can be followed easily by turning the folds in the map. Draw the desired track or tracks on the map. Scale off your track in suitable time sections according to your airspeed, i.e., note against prominent land marks the times at which you should pass over them. Make a particular point of noting your E.T.A. (estimated time of arrival). If it is possible to obtain the wind velocity and direction, plot your course carefully and make use of your compass.

Weather. Secure the fullest possible weather reports before starting. If the flight extends beyond an hour or the weather is at all uncertain, always wire or telephone ahead to get a report on conditions at your destination. Get an intermediate report if there is bad country in between. Obtain a weather chart, if possible, and study it yourself.

Make certain that you carry:

(a) An emergency tool kit.

(b) Screw pickets, lines and engine covers.

(c) Engine and aircraft book and C of A.

(d) Pilot's license.

(e) An emergency container.

(f) A couple of large brown paper bags for the benefit of possible air-sick passengers.

Always notify your destination of your E.T.A. by wire or telephone.

If you are going to the U.S.A. be sure to get customs' clearance out and wire ahead to notify customs of your movements.

Cargo. Check the weight, distribution and security of your load.

Passengers. If you carry a passenger, never leave him alone in the plane with the engine running.

In the Air. Fly at a safe height, ordinarily not less than 2,000 feet. If possible, keep within gliding distance of suitable landing fields. Do not fly over water (on wheels) beyond gliding distance to land. Read your map as you go along and note wind drift if any and make necessary corrections for it. Note the drift of cloud shadows on the ground and if they are moving in your general direction and if you are bucking a head wind, move into the region of the clouds and avail yourself of the helping wind.

If you are heavily loaded and have difficulty getting height, fly under cumulus clouds if any are about. There is an up current under each cloud that will aid you in gaining altitude.

Make the fullest use of your instruments, noting from time to time:—

(a) The oil pressure.

(b) The oil temperature.

(c) The R.P.M. (keep at normal cruising).

(d) The altitude.

(e) The airspeed.

(f) The compass reading.

These instruments are put there for your benefit; don't ignore them; become conscious of your instruments.

Forced Landing. In the event of forced landing observe the following procedure:

(a) Ascertain, if possible, the cause of the trouble.

(b) Note the extent of damage done, if any.

(c) Note whether the field is sufficiently good for a helping plane to land in safety. If not, look for a safe field in the vicinity.

(d) Locate yourself on the map, noting particularly highway and town or village.

(e) Get someone to guard the plane while you go for help.

(f) If telephoning, be sure to get the number you are phoning from.

(g) Telephone or wire your home aerodrome giving without fail every point mentioned above from (a) to (f) inclusive.

(h) Notify your destination of the nature of the delay.

(i) If you are doing interstate flying, notify police or customs of your location and await their instructions.

Bad Weather. **Never** fly into a thunderstorm. If you encounter conditions of low visibility you may have to make a quick decision. You may:

(a) Fly over a storm.

(b) Go around it.

(c) Follow the clouds down to the ground, and if you cannot get good visibility ahead **TURN BACK. NEVER ATTEMPT TO FLY WHERE YOU CANNOT SEE,** unless you are equipped for systematic instrument flying and know how to use it.

Strange Airports. It is good policy to fly around a strange airport at a distance noting the runways, wind direction, rough areas and obstacles and circuit in use, before landing. Observe air regulations carefully.

Be careful to report to the proper authorities immediately on landing. Give necessary instructions as to the housing and servicing of your plane and when it will be needed again.

Keep yourself informed as to the time of sunset and dark and always calculate your flight with a margin of safety in terms of daylight of at least half an hour.

Once again: **DON'T HURRY.** There'll always be another to-morrow; but there'll never be another pilot — just like you.

QUESTIONS

(1) As a pilot, what points would you observe in running up an engine in zero weather?
What are the points to be observed in starting an engine?

(2) You have been compelled to make a forced landing due to engine failure while on a cross country flight. A wing-tip has been damaged in landing. Explain what steps you would take to facilitate the resumption of the flight?

(3) State briefly the points you would observe in making a daily inspection of an aeroplane:

(a) on ground before starting

(b) after getting into cockpit.

(c) in the air.

(d) on your return to the ground.

RIGGING

Treated under four headings, viz:—

(i) Definitions. Use of Instruments.

(ii) Rigging position. Erection and truing of Centre Section. Checking rigging.

(iii) Rigging defects: cause and remedy.

(iv) Two hours spent on practical rigging.

The following notes on rigging are submitted for one purpose only, i.e. to enable the pilot to intelligently inspect and check the rigging of an aeroplane. No attempt is made to touch upon the large field of experience in assembly of parts, tensioning of wires, etc., that the good rigger must have. Rigging is not a classroom subject and it is essential that as much of the work as possible be carried out on an instructional air frame.

The use of the conventional 2 seater, tractor biplane is assumed.

DEFINITIONS—USE OF INSTRUMENTS

Lesson No. 1

The instructor should assemble the class before an airframe and name and describe to them the principal components.

(i) **Angle of Incidence** (Designer's)—The angle between the neutral lift line and the direction of motion.

(ii) **Angle of Incidence** (Rigger's)—Angle between the chord of the wing and the horizontal with the aircraft in rigging position.

(iii) **Dihedral**—The angle of intersection of the main planes at the centre section.

(iv) **Stagger**—The distance the upper plane is forward of the lower plane with the aircraft in rigging position.

(v) **Datum Line**—The name given to that reference line on the fuselage, viewed in side elevation, from which all measurements both angular and linear are made.

(vi) **Rigging position**—Placing the aircraft on trestles clear of the ground. The datum line must be horizontal and the fuselage laterally level.

Since checking the rigging involves the use of instruments, it is essential that the student be shown the necessary instruments and taught how to use them.

The following are suggested:—

(i) **Level or Clinometer**—The correct placing of the level and reading the graduate arc. (See figure 2, Plate 1).

(ii) **Steel Tape**—How to hold it and how to read it correctly.

(iii) **Plumb Bob**—How and where to use it.

(iv) **Straight Edge**—How to use and preserve it.

(v) **Trammels**—Correct use.

(vi) **Incidence Board**—Characteristics. Correct use. (See Fig. 3, Plate 1).

(vii) **Dihedral Board**—Characteristics. Correct use.

Each student must be made to handle and use these instruments correctly before the instructional work proceeds any further. Rigging, like most other branches of engineering, is concerned with the taking and recording of exact measurements; to handle instruments incorrectly is worse than useless; hence the necessity for spending some time of this subject.

Figure 2, Plate 1, shows the construction of a level-protractor. An effort should be made to have every member of the class thoroughly familiar with the correct method of reading a vernier scale.

QUESTIONS

How would you check the truth of the following instruments?

A straight-edge.

An incidence-board.

A level.

Is it possible to check the dihedral of an aeroplane by the use of linear instead of angular measurement?

How is this done?

RIGGING POSITION: ERECTION AND TRUING OF CENTRE SECTION; CHECKING RIGGING

Lesson No. 2

R.P. An aircraft in rigging position is placed on trestles so that the fuselage together with the undercarriage is completely clear of the ground. Care must be taken to place the trestles directly under upright members in the fuselage so as to avoid the possibility of bending the longerons. The datum line of the plane (usually the top longerons at the rear cockpit, sometimes the engine bearers) must be made level. Lateral level is usually attained by placing a straight edge across the fuselage, at right angles, resting on the top longerons, and placing packing blocks under the fuselage till the straight edge reads level. Care must be taken that these packing blocks, if used, are solid, as any tendency of the fuselage to rock will make further work impossible. Any change in the position of the fuselage will necessitate a checking of both lateral and longitudinal level.

Having placed the aircraft firmly in the R.P. the centre section is now checked for truth. The importance of this part of the work cannot be overstressed. The centre section is the foundation on which the setting of the main planes is based so that an error will make endless trouble later on.

The student having been given the following data:—

(i) Angle of incidence of the main planes.

(ii) Angle of incidence of the tailplane.

(iii) Dihedral angle.

PLATE I

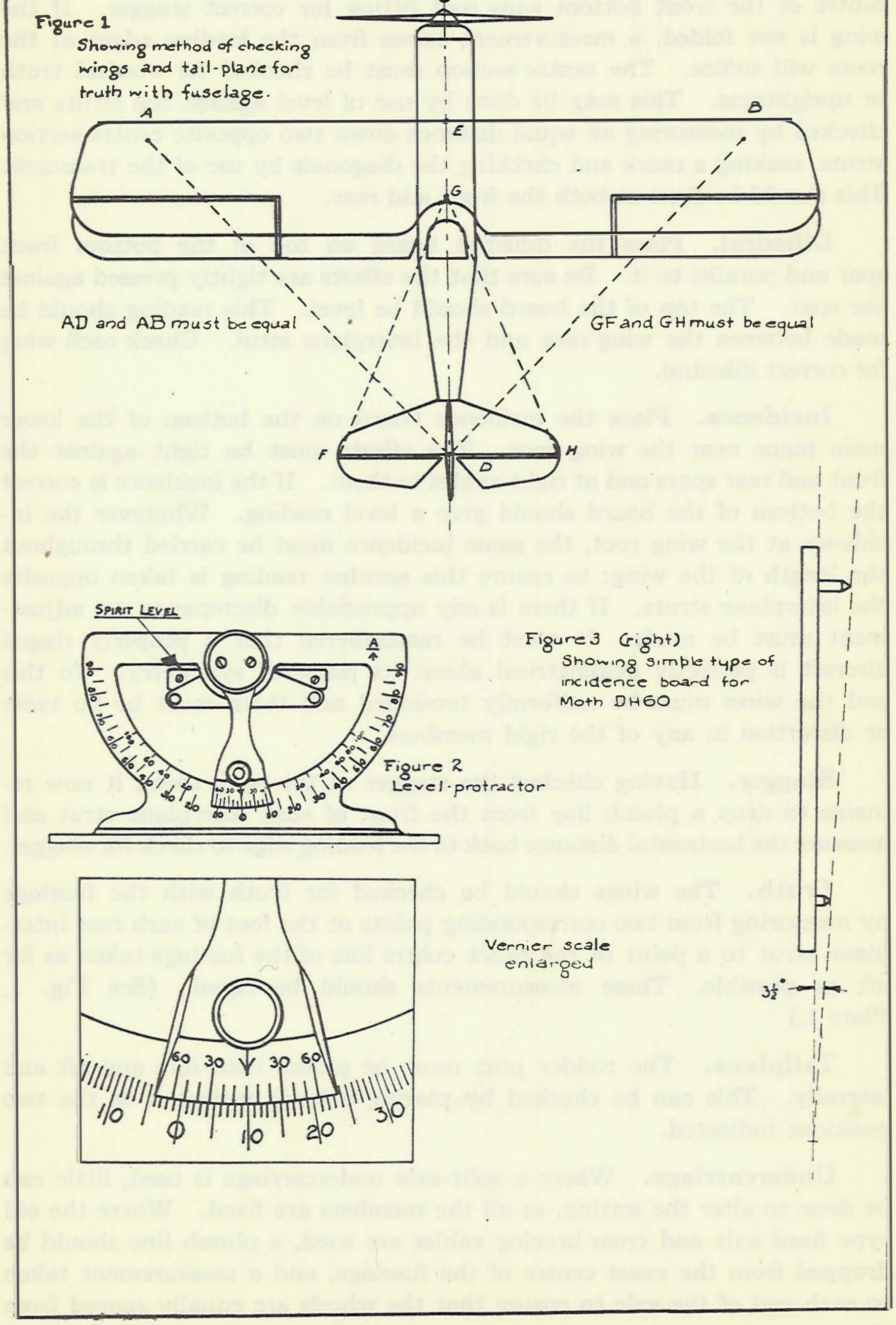


Figure 1
Showing method of checking wings and tail-plane for truth with fuselage.
A
B
C
E
G
F
H
D
AD and AB must be equal
GF and GH must be equal
SPIRIT LEVEL
A
Figure 3 (right)
Showing simple type of incidence board for Moth DH60
Figure 2
Level protractor
Vernier scale enlarged
60 30 0 30 60
10 0 10 20 30
3½"

(iv) Stagger.

(v) Setting of the fin.

(vi) Tolerances allowed.

Centre Section: A plumb line is dropped from the centre of the front top wing root fitting on each side, and a measurement taken to the centre of the front bottom wing root fitting for correct stagger. If the wing is not folded, a measurement taken from the leading edges at the roots will suffice. The centre section must be checked for vertical truth or uprightness. This may be done by use of level against the struts and checked by measuring an equal distance down two opposite centre section struts, making a mark and checking the diagonals by use of the trammels. This should be done at both the front and rear.

Dihedral. Place the dihedral board on top of the bottom front spar and parallel to it. Be sure that the offsets are tightly pressed against the spar. The top of the board should be level. This reading should be made between the wing root and the interplane strut. Check each wing for correct dihedral.

Incidence. Place the incidence board on the bottom of the lower main plane near the wing root. The offsets must be tight against the front and rear spars and at right angles to them. If the incidence is correct the bottom of the board should give a level reading. Whatever the incidence at the wing root, the same incidence must be carried throughout the length of the wing: to ensure this another reading is taken opposite the interplane struts. If there is any appreciable discrepancy an adjustment must be made. It must be remembered that a properly rigged aircraft is perfectly symmetrical about its plane of symmetry. To this end the wires must be uniformly tensioned and there must be no twist or distortion in any of the rigid members.

Stagger. Having checked the stagger at the wing roots, it now remains to drop a plumb line from the front of each interplane strut and measure the horizontal distance back to the leading edge to check for stagger.

Truth. The wings should be checked for truth with the fuselage by measuring from two corresponding points at the foot of each rear interplane strut to a point in the exact centre line of the fuselage taken as far aft as possible. These measurements should be equal. (See Fig. 1, Plate 1.)

Tailplane. The rudder post must be plumb both fore and aft and laterally. This can be checked by placing a level against it in the two positions indicated.

Undercarriage. Where a split-axle undercarriage is used, little can be done to alter the setting, as all the members are fixed. Where the old type fixed axle and cross bracing cables are used, a plumb line should be dropped from the exact centre of the fuselage, and a measurement taken to each end of the axle to ensure that the wheels are equally spaced from the centre.

RIGGING FAULTS AND THEIR CORRECTION

Lesson No. 3

Note:—This table is intended as a guide to assist in discovering the causes of certain faults. In all cases designer's rigging instructions should be rigidly observed.

Symptom	Cause	Remedy
Directional stability bad (i.e., machine does not fly straight.)	(*a*) Angle of incidence of main planes, or tailplane wrong, alignment of fin wrong.	(*a*) Measure and correct.
	(*b*) Alignment of fuselage wrong.	(*b*) Measure and correct.
	(*c*) Dihedral wrong.	(*c*) Measure and correct.
	(*d*) Struts or streamline wires not true in line of flight.	(*d*) Measure and correct.
	(*e*) Surfaces distorted.	(*e*) Measure camber and inspect leading and trailing edges of planes.
	(*f*) Ailerons out of alignment.	(*f*) Check alignment and gap of ailerons, ensuring that the control column is in the neutral position.
	(*g*) Elevators not in prolongation of tailplane on both sides.	(*g*) Align elevators with tailplane, ensure that control column is in neutral position, and tailplane in mean position if fitted with variable incidence gear.
	(*h*) Fin not in alignment giving the effect of slight rudder.	(*h*) Measure and correct.
Lateral trim bad (i.e., machine flies one wing down).	(*a*) Angle of incidence wrong on one or both sides.	(*a*) Measure and correct.
	(*b*) Surfaces distorted.	(*b*) Measure camber and inspect leading and trailing edges of planes.
	(*c*) Dihedral wrong.	(*c*) Measure the dihedral. The dihedral on both planes must be balanced.
Fore-and-aft trim faulty. (i.e., machine nose or tail heavy).	(*a*) Stagger may be wrong.	(*a*) Measure and correct. See that fittings have not pulled into wood.
	(*b*) Angle of incidence of main planes wrong.	(*b*) Measure and correct.
	(*c*) Angle of incidence of tailplane wrong.	(*c*) Check fuselage for truth; tailplane may be correct relative to rear of fuselage, and wrong compared with datum line.
	(*d*) Angle of incidence of tailplane wrong.	(*d*) Measure and correct.

Note.—Be careful not to give the tailplane an angle of incidence greater than specified, as this may render the aeroplane uncontrollable longitudinally.

QUESTIONS

(1) How would you check a Moth aeroplane for truth in rigging? Give full details of procedure, paying particular attention to sequence.

(2) What are possible causes of the following defects in an aeroplane in flight? Describe in detail and give method of correction.

(a) Aeroplane tends to turn to the right.

(b) Aeroplane tends to fly right wing low.

(c) Aeroplane tends to fly nose heavy.

(3) Describe in detail a method of truing up an undercarriage fitted with cross bracing wires.

(4) If control stick is put hard over to the right what position should the left aileron be in?

(5) What method is used to determine when the streamline wires are in safety in the fork ends?

(6) Describe how you would box up the main planes, also how you would determine which are the front and which the rear landing and flying wires.

PRACTICAL RIGGING

Lesson No. 4

This should be confined to **checking** the rigging of an aeroplane and correcting the faults, if any discovered. Great care must be taken to observe the correct sequence in carring out these operations:—

1. Set rigging position.
2. Check truth of centre section.
3. Check dihedral. Correct by use of front landing (and flying) wires.
4. Check incidence. Correct by use of incidence or stagger wires and rear landing and flying wires.
5. Check stagger. Correct by use of incidence or stagger wires and rear landing and flying wires.

   Note that corrections for incidence and stagger must be made together as the same wires are used for both.
6. Check truth of wings, tailplane, etc., with fuselage.

Note.—In all practical work it is advisable to split the class into groups of five or six students. These groups should be directed through the different stages of the work progressively under the supervision of an experienced pilot or engineer.

ENGINES

Treated under the following headings in five periods of one hour each:

1. (a) Description and names of engine parts: definitions.
   (b) The four cycle principle.
2. Valve Timing and Timing Diagram.
3. Wiring system and Magneto.
4. Carburation.
5. Lubrication systems.

(a) DESCRIPTION AND NAMES OF ENGINE PARTS; DEFINITIONS

Lesson No. 1

General classification of engines.

(I) Water cooled.

(II) Air cooled—$\begin{cases}\text{In line}\\\text{Radial}\end{cases}$

Definitions:—

(i) **Bore.**—Internal diameter of cylinder.

(ii) **Stroke.**—Linear distance the piston moves in cylinder, i.e., T.D.C. to B.D.C.

(iii) **T.D.C.**—(Top dead centre) position of crankshaft when piston is at top of cylinder.

(iv) **B.D.C.**—(Bottom dead centre) 180 degrees movement from T.D.C.

(v) **Throw**—The distance from the centre of the crank pin to the centre of the crankshaft.

(vi) **Combustion Chamber.**—Space between piston and top of cylinder when piston is at T.D.C.

(vii) **Compression Ratio.**—Ratio of volume of the cylinder when piston is at T.D.C. to volume when it is at B.D.C. or of the volume of the combustion chamber, to the volume of the whole cylinder with the piston at B.D.C.

(viii) **Specific Gravity.**—Ratio of the weight of any liquid to the weight of an equal volume of water. S.G. of gasoline is about .75, i.e., ¾ the weight of water.

(ix) **Flash Point.**—Temperature at which a fuel will give off vapour that will ignite if exposed to a light or spark.

(x) **Valve Lag.**—Number of degrees a valve closes after T.D.C. or B.D.C.

(xi) **Valve Lead.**—Number of degrees valve opens before T.D.C. or B.D.C.

(xii) **Valve Overlap.**—When the inlet valve opens before the exhaust valve has closed.

(xiii) **Viscosity.**—Resistance of a fluid to change of shape; resistance to flow.

(xiv) **Tappet Clearance.**—Gap between rocker arm and top of valve stem. It allows for proper seating of the valve when it expands through heating.

(b) THE PRINCIPLE OF A FOUR-STROKE ENGINE

The main parts of an engine are:

(I) **Piston:** which slides up and down in the cylinder, drawing in the charge on the down stroke, compressing it on the next, transmitting the power to the crankshaft on the power stroke, and expelling the burnt gases after they have done their work.

(II) **Piston Rings.**—To prevent leakage of the petrol mixture between the piston and cylinder walls, split cast-iron spring rings are fitted. These are located in grooves cut in the top of the piston and press against the cylinder walls. The number of rings used varies according to the design of the engine and the type of rings. The joint where the piston ring is split is cut at an angle of 45°, the reason for this is that it prevents a ridge wearing in the cylinder wall where this joint reciprocates. The width of the gap is laid down by the manufacturer and should be strictly adhered to. A general rule is 1/16 in. to every foot of diameter.

(III) **Scraper Ring.**—This ring is similar to the piston ring, and is fitted on the bottom of the piston. It prevents an excess of oil getting to the piston and eventually past the piston rings, where it would burn and so carbonise the rings and piston.

(IV) **The cylinder** in which the piston slides and in which the explosion takes place.

(V) **A crankcase** in which is mounted the crankshaft and on which the cylinders are mounted.

(VI) **A crankshaft** which, on revolving, turns the propeller. It converts reciprocating motion into rotary motion.

(VII) **A connecting rod** — connecting piston to crankshaft.

(VIII) **An inlet valve** which opens to admit the explosive mixture.

(IX) **An exhaust valve** which opens to expel the burnt gases.

(X) **A camshaft** which opens and closes the valves as required.

(XI) **A carburettor** in which fuel is mixed with air to form a combustible mixture.

(XII) **A magneto** which generates a high voltage current and transmits it to the spark plug to fire the mixture.

PLATE I

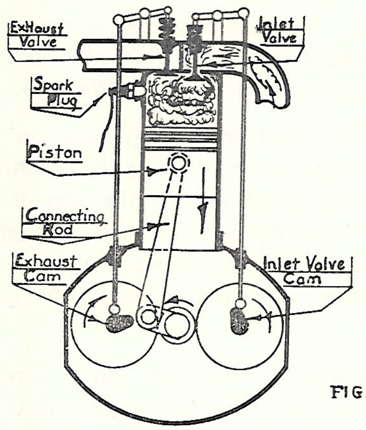


FIG. I

INLET STROKE
Inlet valve open, piston travelling down draws combustible mixture into cylinder.

COMPRESSION STROKE
Both valves closed, piston travelling upwards in cylinder, compressing the mixture.

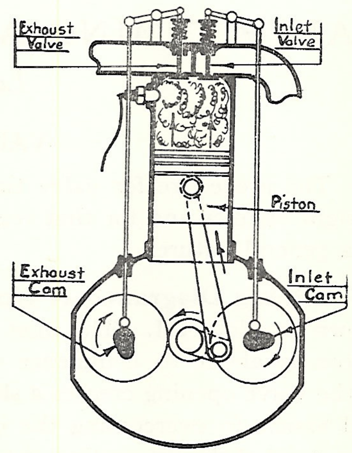


FIG. II

The four strokes are:—

The downward suction stroke—As the piston travels down the cylinder the inlet valve is opened by the cam and the piston sucks in a mixture of petrol and air from the carburettor. Shortly after the piston reaches the bottom of the stroke the inlet valve is made to close. (See **Fig.** 1, Plate I).

The upward compression stroke.—The piston now rises in the cylinder, forcing the gas upwards and compressing it into a small space. On this stroke both valves remain closed. When the piston is almost at the top of its stroke the gas is ignited by a high tension current of electricity jumping across the points of the sparking plug. (See **Fig.** 2, Plate **I**).

The downward power stroke.—The effect of the ignition on the gases is to cause a large increase in the temperature of the gases. Due to this increase of temperature, the expanding gases act on the top of the piston, driving it down the cylinder and thereby rotating the crankshaft through the medium of the connecting rod. When the piston is approaching the bottom of the stroke, the exhaust valve is opened, allowing the gases to escape. (See **Fig.** 1, Plate II).

The upward exhaust stroke.—With the exhaust valve already opened, the piston rises in the cylinder, sweeping the burnt gases out. It is impossible to expel all the burnt gases, for when the piston is at the top of its stroke the contents of the combustion chamber still remain. At this position the piston is ready to commence another cycle of operations, and as the piston begins to descend the exhaust valve closes. (See **Fig.** 2, Plate II).

VALVE TIMING AND TIMING DIAGRAM

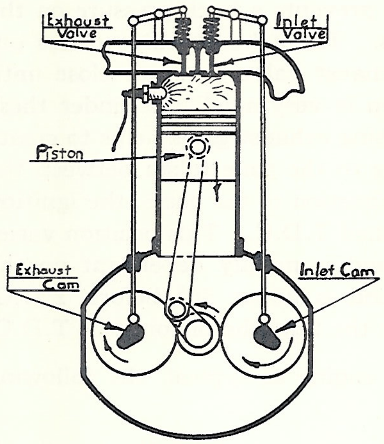
Lesson No. 2

VALVE TIMING

The procedure for valve timing varies somewhat between radial and upright engines and for that reason the following notes on the subject are of a general nature.

Timing Diagram.—A typical valve and ignition timing diagram is shown in Plate III. The inlet valve is opened just before T.D.C. The piston is about to commence the downward suction stroke. The lead in the valve opening creates a slight depression in the combustion chamber and assists in overcoming the inertia of the gases in the induction pipe. The speed of the descending piston is greater than the speed of the incoming gases, so that a slight depression is still in the cylinder when the piston is at the bottom of its stroke. The valve is, therefore, kept open until the pressure in the cylinder is equal to atmospheric pressure. This position is approximately 63° past B.D.C. The lag in the valve closing increases the amount of charge entering the cylinder.

PLATE II



POWER STROKE

Both valves closed, piston being driven downwards by the force from the expanding gases.

FIG. I

EXHAUST STROKE

Exhaust valve open, burned gases being swept out of cylinder by the piston travelling upwards.

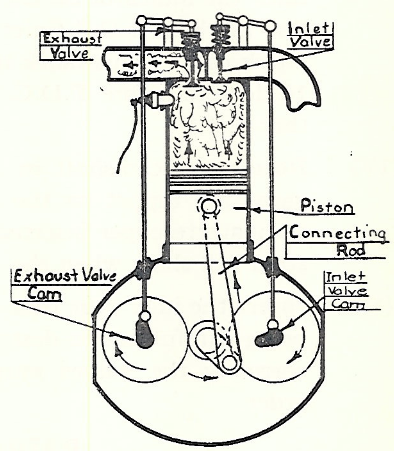


FIG. II

On the power stroke the exhaust valve is opened about 54° before B.D.C. At this point the expanding gases are exerting little pressure on the piston head. When the crank is at an angle of 45° to the vertical, the angle between the connecting rod and the crank arm is so small that the remaining pressure in the cylinder would be of very little value. When the exhaust valve opens the burnt gases commence to leave the cylinder by their own pressure and so assist in scavenging the cylinder. The exhausting of the gases at this point also prevents a back pressure on the piston when the change of stroke occurs. The exhaust valve closes on, or just after, T.D.C.; in this case the exhaust valve does not close until after the inlet valve opens. This overlap is very small but under these circumstances the momentum of the outgoing exhaust gases helps to create a suction on the inlet valve port. Owing to the time taken between the moment of ignition and the complete combustion of the gases, the ignition must take place before the piston has reached T.D.C. This position varies according to the design of the engine, and is mainly dependent on the speed of the piston. An average position is about 36° before T.D.C. This allows combustion to be complete by the time the piston is at T.D.C.

Valve Timing.—Taking a Gipsy 1 engine as typical, the following steps are followed:—

(I) Set the valve clearance correctly as required by the handbook (cold clearances).

(II) Disconnect the camshaft from the crankshaft.

(III) Rotate the crankshaft in the direction of rotation of the "prop" until the indicator on the rear of the propeller hub is opposite the line marked "I.O." (inlet opens) on the plate at the front of the crank case. This mark is so placed that the piston will stand at 10 degrees before T.D.C. if the inlet valve is designed to open at that point.

(IV) Rotate the camshaft in its required direction until the cam engages the tappet on the inlet valve on No. 1 cylinder. A piece of cigarette paper inserted between the rocker arm and the valve stem will show when the cam starts to open the valve.

(V) Insert the idler gear that connects the camshaft to the crankshaft, being careful not to destroy the setting of either. If this is done correctly the valves must now open and close in their proper order.

RADIAL ENGINE

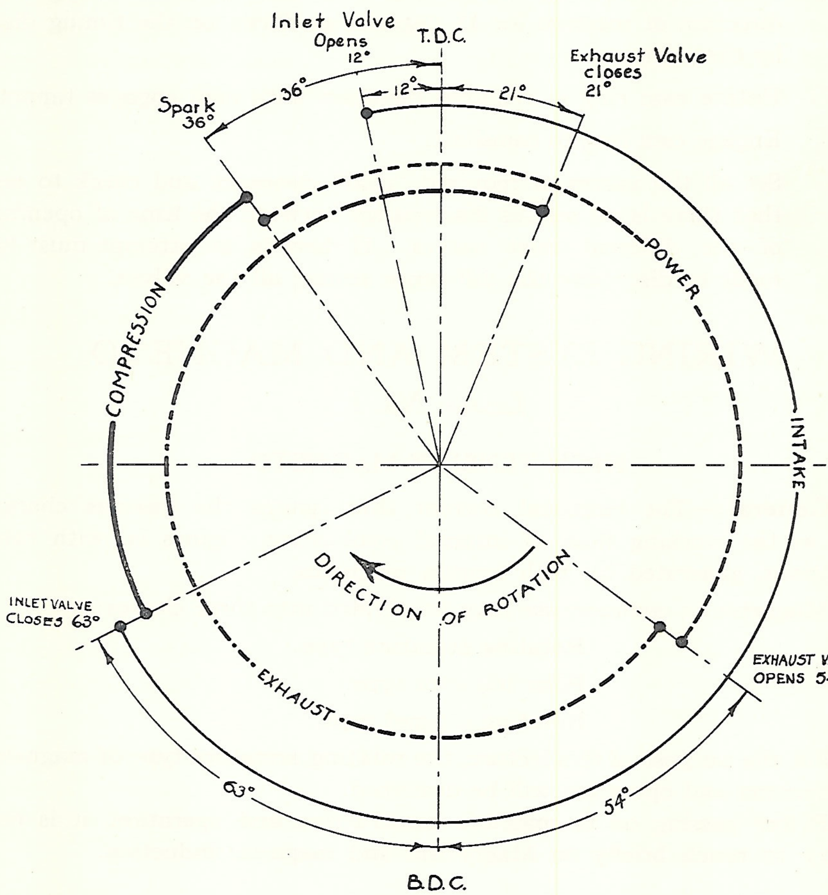
(I) Set the clearance on No. 1 inlet valve at the "hot" clearance given in the book of instructions.

(II) Remove propeller and place a timing disc on the crankshaft.

(III) Attach a fixed pointer to the crankcase.

(IV) Disconnect the camshaft from the crankshaft.

PLATE III



VALVE TIMING

INLET OPENS : 12° B.T.C.
" CLOSES : 63° A.B.C.
EXHAUST OPENS: 54° B.B.C.
" CLOSES: 21° A.T.C.

IGNITION TIMING

36° B.T.C. — FULL ADVANCE

GYPSY MK.I TIMING DISC

(V) Insert T.D.C. indicator in spark plug port of No. 1 cylinder.

(VI) Rotate crankshaft in direction of rotation and note first movement of indicator. Continue until second movement of indicator is noted. Count the number of degrees between these points and mark the middle point between them. This will give you true T.D.C.

(VII) If inlet opens 15 degrees before T.D.C. turn crankshaft in opposite direction of rotation for 15 degrees, as shown on the timing disc by the pointer.

(VIII) Rotate cam ring in required direction until cam engages tappet.

(IX) Engage cam ring to camshaft.

(X) Set all the valves at required "cold" clearance and check to see that there is no serious discrepancy between the time of opening of the different inlet valves. If there is, an attempt must be made to distribute the difference among all the valves.

WIRING SYSTEM AND MAGNETO

Lesson No. 3

HIGH TENSION MAGNETO

General:—The electrical current that ignites the gaseous charge used as the working fluid of internal combustion engines is, with rare exceptions, generated by high tension magnetos.

Magnetos in common use may be divided into three classes:—

Rotating armature type.

Polar inductor type.

Rotating magnet type.

For the purpose of this lecture, the rotating armature type of magneto construction and operation will be described.

Before passing on to magneto construction and operation, it is necessary to touch briefly on Magnetism and magnetic induction.

MAGNETISM

Magnetic circuit:—Magnetic lines of force are invisible waves that pass from one pole of the magnet to the other. The lines of force pass from the north (N) pole to the south (S) pole, outside of a permanent magnet circuit.

POLARITY OF A MAGNET

Fig. 1.—A horseshoe type of permanent magnet.

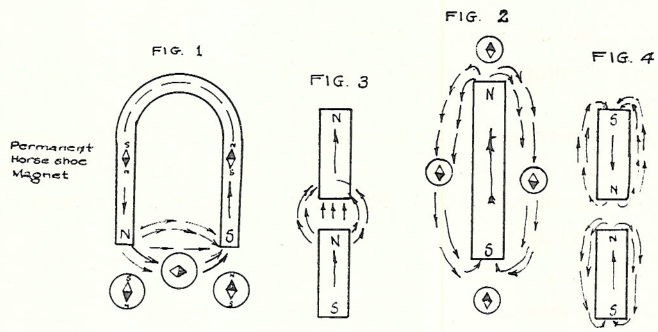
Fig. 2.—A bar type of permanent magnet.

Fig. 3.—Showing unlike poles attract.

Fig. 4.—Showing like poles repel.

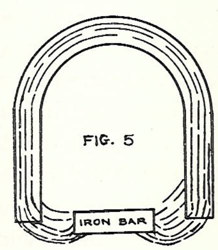
If a compass (as shown in Figs. 1 and 2) is placed at the N. pole end of a magnet, the N. end of the needle will point away from the N. pole, or with the direction of the flow of the lines of force, which is always out at the N. and in at the S. pole. This is why the N. pole of a magnet attracts the S. pole of a compass needle, and why the S. pole of a magnet attracts the N. pole of a compass needle. Like poles repel and unlike poles attract because other lines of force pass in a circuit, N. to S. **outside,** and S. to N. **inside** of a magnet.

POLARITY OF A MAGNET



A bar magnet is shown in Figs. 2, 3 and 4. It will be noticed that the magnetic circuit is the same as in the horseshoe magnet used on magnetos of the rotating armature type. The magnetic lines flow through the air from N. to S. pole outside of the magnet and through the magnet from S. to N.

If an iron bar is placed between the poles of a magnet, (Fig. 5), the lines of force will flow freely through the iron bar, because the air gap between the poles offers about 280 times the resistance that the iron bar does. The iron bar tends to gather and collect stray lines of force, and to concentrate the lines. Thus a great many more lines of force are obtained for transmission across the gap by using the iron bar.



Soft iron is generally used for the armature core on a magneto because soft iron will not retain its magnetism after the magnetic effect has been removed. In generating electric current, this is a very important factor, that is, the iron bar must become magnetized and demagnetized as quickly as this change of action is desired.

Magnetic field of force is the space around or between the magnets where the magnetic lines of force pass.

Electromotive force (E.M.F.) is the force or pressure which moves electricity, and the unit of electromotive force is **one volt.**

When current is sent through a wire or coil from some source the EMF is supplied from that source.

Having now acquired a knowledge of the simple laws governing magnetism, magnetic lines of force and their actions we can now investigate the high tension magneto. The high tension magneto is not only a mechanical generator; it combines all the elements of a complete ignition system, less the switch and spark-plugs. It performs three separate essential functions:—generating current; transforming the current to a high pressure; distributing the high tension current to the different individual cylinders.

Its principal component parts are:—

Permanent magnets, made of Tungsten steel, which retains magnetism for long periods.

Armature Core: soft iron laminar structure. Primary winding around the core, usually of No. 18 enamelled wire. Secondary winding over primary winding of about No. 38 enamelled wire silk covered.

Breaker mechanism.

Collector Ring.

Carbon Brushes.

Distributor face.

Magneto base and the necessary gearing to drive and couple magneto to engine.

FUNCTION OF COMPONENT PARTS

Having previously discussed permanent magnets, to some extent, let it suffice by saying that the magnets are the source of the current generated and provide the magnetic field in which is placed the **armature core.**

The armature core consists of a number of soft iron plates, constructed after the shape of the spool, attached to the armature shaft, so that they rotate between the poles of the magnet. The core is built up of plates because a number of plates, so constructed, can be magnetized or demagnetized with greater rapidity than a core of solid construction. It functions the same as the bar of iron previously explained.

Primary winding is wound around the core, and usually consists of around 200 turns of No. 18 to 24 gauge insulated copper wire. A low tension alternating current is generated in this winding.

Secondary winding is wound over the primary winding, usually consisting of about 12,000 turns of No. 35 to 38 gauge insulated copper wire, the insulation being enamel and silk-covered. The ratio of windings is about 60 to 1. The current in this winding is high tension alternating.

Carbon brushes: these are used principally for collecting current from rotating parts of a magneto and transferring it to stationary parts, or vice versa, usually three to a magneto; one to run the current from the contact

point to ground through the frame of the magneto; one to collect the secondary current at the collector ring and carry it to the rotor; one to distribute current to the segments of distributor face from rotor arm.

The distributor is usually made of bakelite with brass segments built into it. The segments are connected by wire to the spark plugs of the individual cylinders of the engine.

Contact breakers: these provide a means of opening and closing the primary circuit at the desired moment.

When the points (Fig. 6) are closed, the current flows to ground. When open (Fig. 7), the current's path to ground through that medium is broken.

The contact breakers are securely fastened to the armature shaft, and rotate with it. They consist chiefly of a stationary insulated contact point (1) and a movable contact point (2) on one arm of the bellcrank (3). Both these parts are mounted on a brass disk (4), which is fastened to the armature shaft and rotates with it.

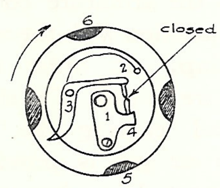


FIG 6

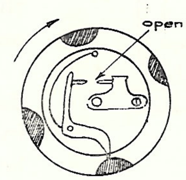


FIG. 7

The stationary contact (1) is insulated from the disk (4), while the movable contact is in metallic contact with it, and the disk is grounded to the frame of the magneto by a carbon brush. The contact breaker is surrounded by a housing, to the interior of which, at diametrically opposite points, are secured steel cam blocks (5 and 6).

Ordinarily, the two contact points are kept in contact by a spring. As the disk rotates, the outer arm of the bellcrank comes in contact with the steel cams, whereby the contact points are separated momentarily; as soon as the bellcrank passes the cam block, the spring brings the two points together again.

The stationary contact block is connected with one end of the primary winding through a long screw which is screwed into the armature shaft. The other end of the primary winding has metallic connection with the armature core, or is grounded through that medium.

Collector Ring: is made usually of hard rubber or bakelite, with a brass ferrule surrounding it, against which ferrule an insulated carbon brush bears. The collector ring spool has wide flanges to prevent the high tension current from escaping.

Rotor Arm: the rotor arm passes the high tension current through a brush fixed to the end of the rotor arm to the insulated brass segments of the distributor.

Magneto Base: this is composed of some non-magnetic metal. It provides a means of carrying the upper structure of the magneto and is a means of fastening the complete magneto to the engine.

A condenser consists of conducting surfaces placed between insulating surfaces, known as dielectric. The conducting surfaces are sheets of thin tinfoil, cut with conducting tabs, which project beyond the ends of sheets of "mica" on which is placed a sheet of tinfoil, the latter being arranged so that the tabs project at alternate ends. The mica overlaps all around about an inch to prevent discharging from the edges. The capacity of a condenser depends upon the size and number of sheets of tinfoil and the thinness and character of the dielectric separating them. When a sufficient number have been assembled, the projecting ends are clamped together and a flexible wire lead connected to them. It is then connected in multiple with the breaker points. A condenser practically eliminates sparking at the contact points.

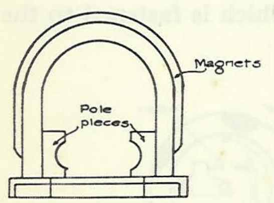


FIG. 8

Pole pieces (or shoes, Fig. 8) are constructed of the same material as the armature core, usually, and have constant connection with the magnets.

Safety Spark Gap. In order to prevent damage to the armature in case of a short circuit in the secondary lead, causing the voltage to become excessive, an air gap is provided across which the current can pass on to ground without doing damage.

Magneto Operation. When the armature revolves between the poles of the magnets and reaches a position at which the maximum flow of flux is flowing through the armature core, a current is generated in the windings. With the points closed, the primary circuit is complete, and the current so generated flows on across the breaker points to ground. This current sets up a field of its own, which is in opposition to the field of the magneto.

On the opening of the contact points, the flow to ground of the current is stopped, causing the field associated with it to collapse, falling inwards on itself, so cutting the conductors of the secondary winding; causing a current to be induced in the secondary which is in the same direction as that supplied by the magnets. The primary also has a current induced owing to its own field collapsing, but due to the small number of turns of wire on the primary, the self-induced current is small, and is absorbed by the condenser, leaving the core and primary ready for the next flow of flux in the reverse direction through the core.

The high tension current induced in the secondary winding is led to the collector ring, and from there to the distributor face and thence to the plugs.

The result of one complete revolution of the armature is an induced current for about 25 degrees of rotation; very little current for the next 155 degrees; a current in the reversed direction for the next 25 degrees; and very little current for the remaining 155 degrees. A magneto operating thus may be used for ignition twice in its revolution.

SPARKING PLUGS

It is of vital importance that an aero plug should be absolutely reliable, as failure may cause serious consequences. For insulation, mica is used on most plugs, because it remains a good insulator at a far higher temperature than either porcelain or steatite. The shape of the spark gap, which, in the case of plugs for automobile engines is of quite secondary importance, becomes of primary importance in the case of aircraft engines. A special type of gap has been developed.

The chief difficulty to be overcome is the effect of heat. The plugs have to be very strong mechanically, and the insulation must be of such a nature that it will not fail at an extraordinary high temperature; also special means should be taken to cool the centre insulated electrode, which would otherwise get too hot and cause pre-ignition.

The Magneto Switch.—If the low-tension current is conducted back to the frame of the magneto instead of being allowed to pass through the contact breaker, it will prevent the generation of the high-tension current. To switch off a magneto it is only necessary to ground the low-tension current. Thus, when the magneto is switched off, the current is really switched on to the earth.

Advance and retard.—As the complete combustion of the gases does not take place simultaneously with the spark, it is necessary to alter the position of the spark in accordance with the speed of the piston. When the engine is running slowly, the spark may be timed to take place when the piston has reached the top of the compression stroke. If the engine is running fast the piston will have covered a greater distance in the same time, which necessitates the timing of the spark to take place before the piston has reached the top of the compression stroke. The time of the ignition can be varied by altering the position of the cam that operates the contact breaker. This cam is fitted to a housing which can be given a small rotary movement.

Internal timing of a magneto.—Whenever the points of the contact breaker separate, a high-tension current is generated in the secondary winding, and at this moment it is necessary that the brush of the distributor should be in contact with one of the metal segments of the distributor plate. This can be obtained by accurately engaging the gear wheels between the armature and the distributor. The exact position of the carbon brush on the metal segment depends upon the position of the contact breaker housing, whether it is advanced or retarded. When the ignition is fully advanced, the distributor brush should be at the beginning of the metal segment.

Recapitulation:—To fire a charge of gas in the combustion chamber four things happen simultaneously:—

(I) The rotating armature is in the position of maximum flux.

(II) The contact breakers are opening.

The ignition point is the temperature at which the oil gives off vapour in sufficient quantities to be permanently inflammable, and is generally about 30°F. to 50°F. above the flash point.

The flash points and ignition points of gasoline and benzol are shown below:—

Spirits:—	Specific Gravity	Boiling Point Commence at	Boiling Point Complete at	Flash Point
Gasoline......	.67 – .74	115 F.	290 F.	Below 73 F.
Benzol........	.67 – .84	150 F.	300 F.	Below 76 F.

In its liquid state gasoline is a non-combustible oil which has a specific gravity of from .67 to .74. When mixed with air, even under ordinary atmospheric conditions it will vapourize most readily and becomes highly combustible. The quantity of air necessary for perfect combustion varies with the condition of the atmosphere.

2. DEFINITION OF CARBURATION AND CARBURETTOR

For an internal combustion engine to develop maximum power per unit quantity of fuel, perfect combustion is essential, and to obtain perfect combustion, perfect carburation is necessary. The term "Carburation" as applied to gasoline engines, is the process of mixing the correct proportion of gasoline with air to form the explosive mixture or charge. The apparatus that accomplishes this very important process is styled a "Carburettor".

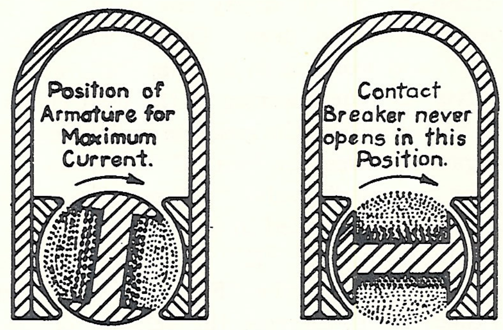
3. FUNCTION OF A CARBURETTOR

A carburettor to be efficient must be designed to be capable of supplying to the engine, under all conditions of speed and throttle opening, a mixture of gasoline and air which will result in complete combustion with maximum power. A mixture which has been found to be satisfactory for all practical purposes, is one of one volume of liquid gasoline to 10,000 volumes of air, or, expressed in weight, one of gasoline to 15 of air. The mixture must be homogeneous, i.e., samples taken from any part of the bulk of the gaseous fuel will be uniform and exactly alike in composition — otherwise the power and running of the engine will be affected. Other desirable features of the aeronautical carburettor are:—

(a) Uniform mixture at all altitudes.
(b) Ability to supply a mixture for ease in starting.
(c) Ability for adjustment to suit climatic conditions.
(d) Flexibility.
(e) Quick acceleration.
(f) Economy of fuel consumption.
(g) Simplicity in design and accessibility.

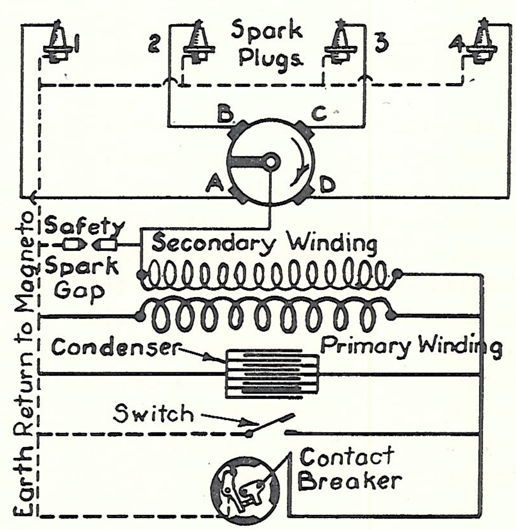
How attempts have been made in the design of the modern aeronautical carburettor, to combine all these desirable features, will now be examined.

PLATE IV



ARMATURE POSITIONS

FIG. I



MAGNETO WIRING DIAGRAM

FIG II

4. SIMPLE SPRAY TYPE CARBURETTOR

The diagrammatic sketch Fig. 1 Plate V illustrates the working principle of a simple spray type carburettor. The gasoline is led from a tank to the float chamber "B" by a pipe either by gravity or at a low pressure. When the float chamber "B" is empty the float "C" is lowered, which causes the balance weights to drop. Owing to these balance weights being pivoted at "c" and working in a collar "d", which is in turn fitted onto the needle valve "D" the lowering of the float raises the needle valve "D" off its seating, so permitting the gasoline to flow into the float chamber. As the level of the gasoline rises, the float "C" also rises and lifts the balance weights, thus closing the needle valve "D" onto its seating, so a constant level of the liquid fuel is maintained in the float chamber. Situated in the mixing chamber is the spray jet "E" which is fed with gasoline from the float chamber. The choke tube "F" which surrounds the top of the jet, is reduced in diameter to increase the velocity of the air at this point and consequently reduce the pressure on the jet. The so termed "suction" on the jet depends upon the difference of pressure at the mouth of the jet and the pressure in the float chamber. The volume of air which is admitted through the main air intake "H" increases with the speed of the engine. Therefore, as the velocity of the air past the jet increases, so the pressure on the jet decreases allowing more gasoline to flow from it. The gasoline issuing from the jet in the form of a fine spray mixes with the air being drawn past it by the engine, and passes through the induction pipe in the form of gasoline vapour. Provided the engine is rotating and its pistons are creating a partial vacuum in the cylinders the quantity of air which passes the jet "E" and consequently the quantity of carburated mixture admitted to the engine, is controlled by the position of the throttle valve which may be opened or closed by means of suitable controls.

For efficient carburation at all speeds of the engine the mixture of gasoline and air must always be of the correct proportion. Unfortunately this ideal mixture is not possible with the type of carburettor now being described. As the throttle is opened and the engine increases in speed the suction in the mixing chamber increases as previously explained, but the flow of gasoline increases greater in proportion than the flow of air, and consequently the mixture becomes too rich. This simple type of carburettor can be adjusted to give an efficient mixture at one engine speed only. As it is necessary to vary the speed above and below the speed for which this carburettor can be adjusted, it is necessary to introduce a device to automatically control the supply of gasoline to weaken and tone down the mixture as the speed of the engine increases, and to strengthen it at lower speeds.

Fig. 2 diagrammatically illustrates how this is done in the Zenith Carburettor.

PLATE V

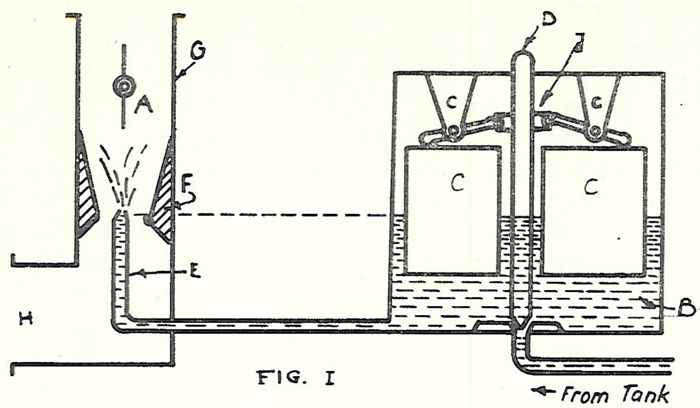


FIG. I

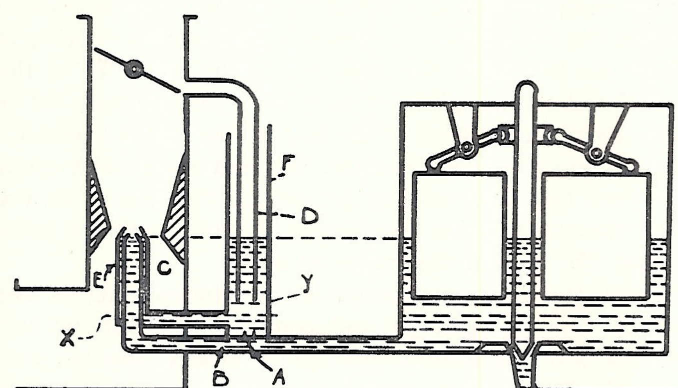


FIG. II

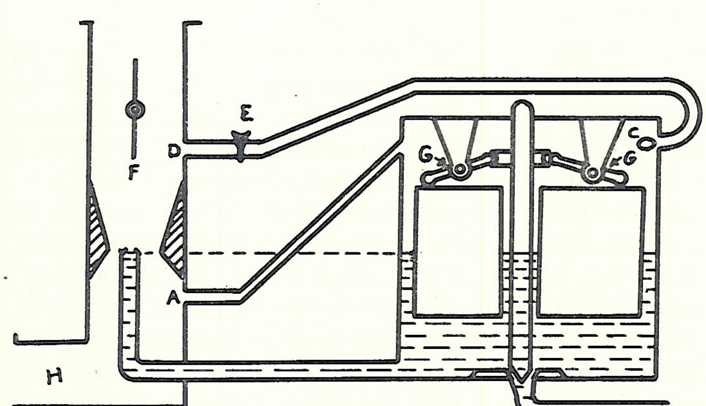


FIG. III

5. ACTION OF ZENITH CARBURETTOR

In general construction the Zenith Carburettor is similar to the simple carburettor illustrated in Fig. 1. Its chief point of difference is the arrangement of the jets. As will be seen by referring to Fig. 2, the Zenith Carburettor has two distinct supplies of gasoline, "A" and "B", from the float chamber to the mixing chamber. The gasoline supply, through the compensator "A" to the slow running jet "D" and compensating cap jet "C", is determined primarily by the head of gasoline (or weight of same) in the float chamber, but as the throttle is opened and the engine speed increased, this supply is restricted by the small orifice of the compensator "A". The head of gasoline in the float chamber is maintained owing to the regulating action of the float and needle valve. The gasoline supply to the main jet "E" is direct from the float chamber and unlimited in quantity. The flow of gasoline from this jet is determined by the suction caused by the engine, and in action is the same as the single jet in the simple carburettor previously explained. When the throttle is practically closed, the suction from the engine is concentrated on the slow running or pilot jet "D". When the height of the gasoline in the well "F" is the same as in the float chamber, this pilot jet supplies a rich mixture for ease in starting. After starting, the level of the fuel in this well is lowered, due to the restricting action of the compensator "A", but a sufficient quantity is maintained to feed the slow running jet to run the engine at very low speed in which throttle position insufficient suction would be present on the jets "C" and "E" to run the engine at all.

As the throttle is opened, the suction on the slow running jet decreases, while the suction on the main jet and compensating cap jet increases, due to the velocity of the air passing through the mixing chamber increasing, until, when the throttle is fully opened, the full force of the incoming air passing through the mixing chamber is acting on the main jet and compensating cap jet only. The suction on the slow running jet at this throttle position is nil.

The main jet and the compensating cap jet, together, are known as the "Compound Nozzle". The centre of main jet "E" is of the usual type and action, because, under suction, the flow of gasoline increases faster than the flow of air. This jet alone would supply a mixture which would become too rich as the speed of the engine increases. The outer, or compensating cap jet "C", has an opposite effect. It delivers only what the well "F" receives, the quantity of gasoline in which is regulated by the gauged orifice "A", known as the compensator, the quantity of gasoline passing through which is only slightly affected by the suction of the engine. When the throttle is fully opened, the level of the fuel in the well drops down to about the level of the dotted line X.Y., and instead of pure liquid gasoline, air, which is admitted at the top of the well, becomes saturated with gasoline as it passes over the surface of the fuel, forming a weak mixture which is sucked up through the compensating cap jet. These two jets, the main jet and the compensating cap jet, in combination, maintain an ideal mixture at all engine speeds.

6. REGULATION OF MIXTURE AT ALTITUDE

With increasing altitude, the flow of gasoline in the usual type of carburettor will increase greater in proportion than the flow of air, and consequently — unless special provision is made — the mixture fed to the engine will become too rich.

Three principal methods are used to "tone-down" the mixture as higher altitudes are reached:

(a) By providing a means to admit more air to the mixing chamber.

(b) By controlling the difference of pressure in the float chamber and mixing chamber.

(c) By direct control of gasoline to main jet.

Carburettors embodying the first method (a) are provided with extra air intakes to the mixing chamber, which are usually situated between the main carburettor throttle and choke tube. The amount of air admitted at this point is controlled by separate throttles which are actuated by suitable controls, by the operator or pilot. More air is admitted to the carburettor as higher altitudes are reached, and consequently the mixture may be "toned-down" during flight.

In carburettors embodying the second method (b) advantage is taken of the fact that the rate of discharge from the main jet, which is in direct communication with the float chamber, is governed by the difference in pressure between the air in the float chamber and the air in the mixing chamber immediately over the jet. By providing a means of altering the pressure in the float chamber, and thereby varying the difference in pressure between this chamber and the mixing chamber, the discharge from the main jet is altered accordingly.

The diagrammatic sketch (Figure 3) illustrates how this is effected.

The float chamber is hermetically sealed. A communication "A" is established between the main air intake of the carburettor and the top of the float chamber. A second communication "C" "D" joins the top of the float chamber to the mixing chamber above the choke tube, and a hand controlled tap "E" is placed in this passage. Provided the engine is running, there will be a certain depression or partial vacuum in the mixing chamber "F", whilst at "H" the pressure will be that of the atmosphere, and the greatest vacuum will be in the choke tube. In all cases the pressure at "A" will be greater than that at "F", because of the resistance offered by the choke tube to the flow of air. If the tap "E" is closed, the discharge from the main jet is determined by the difference of pressure immediately over it and that present in the float chamber "G" which at this time will be the same as at "A". If the tap "E" is opened the pressure in the float chamber "G" is lowered, and it becomes nearer to that which exists at "F", and in this way, the discharge from the main jet is decreased for the reasons stated before. In practice this arrangement is carried out by simply drilling passages in the body of the carburettor itself.

The third hole that will be seen inside the float chamber is to ensure that the compensator works at the same pressure as the float chamber. As the carburettor is adjusted on the ground, with the tap "E" shut it is only necessary to open it more or less to correct the mixture at varying altitudes.

The third method (c) is self-explanatory. A needle valve or its equivalent is arranged to control the amount of gasoline fed to the main jet. This device is usually fitted between the float chamber and the main jet and is actuated by means of suitable controls, by the pilot during flight.

References: Pamphlet published by—The Zenith Carburettor Co., Ltd.

LUBRICATION SYSTEMS

Lesson No. 5

FUNCTIONS OF OIL

Lubricating oil in an engine has three duties to perform, viz:—

(I) Supply a constant film between the moving parts so that there shall be no metallic contact and, hence, a minimum of friction and heat.

(II) In circulation throughout the engine, it removes the heat generated through combustion and friction and thus helps to keep the interior of the engine relatively cool and at a uniform temperature.

(III) It provides a packing body between the piston rings and the cylinder wall which tends to seal the piston against the escape of the gases under the high pressure of the explosion. For this reason it is dangerous to flood the cylinder with raw gasoline because by so doing you may develop friction between the rings and the cylinder wall resulting in scoring, and a part of the power of the explosion will be lost through the escape of gas past the rings.

CHARACTERISTICS OF GOOD OIL

Viscosity: To retain its lubricating and sealing qualities a good oil should retain much of its viscosity under the high temperatures that are encountered in internal combustion engines.

High flash point: For this same reason it is necessary that the oil should have a flash point well in excess of the highest temperature it will encounter in the crankcase.

Low carbon content: In spite of the scraper ring, some of the oil works its way into the combustion chamber where it is burned. It is essential that, in burning, the residue of carbon left should be as small as possible as the presence of large masses of intensely heated carbon in the combustion chamber causes pre-ignition.

It should be noted that the quality and grade of oil used varies with particular engines and with the temperature and the time of year. Every pilot should make himself thoroughly familiar with these matters as well as with the oil capacity, oil consumption, period between oil changes, position and reading of the oil gauge, position and method of cleaning the oil filters, etc. of his engine.

OILING SYSTEMS

Wet Sump: Cirrus and Gipsy 1 engines are typical of the wet sump group. In these the oil is retained in the bottom of the crankcase. The oil pump, running in the oil, forces it by a system of pipes through the crankshaft and other members, after which it falls back into the sump again.

Dry Sump: The inverted Gipsy and Genet engines belong to the dry sump group. In these the oil tank is placed outside of the engine and the oil is pumped to and from it by means of two pumps. One of these pumps, the force or feed pump, takes the oil from the tank and forces it under high pressure through the system. The second, scavenger pump, which usually has twice the capacity of the feed pump, takes the oil from the point at which it collects in the crankcase and returns it to the external tank.

METHODS OF LUBRICATION

Usually several methods of lubrication are used in one engine. Those in common use are:—

(I) **Force Feed:** In this the oil is forced under high pressure through the crankshaft from which it sprays onto the main bearings and big end connecting rod bearings.

(II) **Splash:** The rapid rotation of the crankshaft splashes the oil completely over the interior of the engine as it escapes from the main and con. rod bearings. After a few minutes of running the whole of the interior of the engine is filled with a heavy mist of fine oil particles. This mist or splash provides lubrication for the cylinder walls, wrist-pins, timing gear, camshaft, tappets, etc.

(III) **Hand feed:** The rocker arms, magneto bearings and other external moving parts are frequently lubricated manually. This last and simplest method of lubrication is the one most frequently overlooked in practice as well as in examination papers. Every self-respecting pilot must familiarize himself with the quality of grease or oil used in these operations and the frequency with which they are applied, as well as the method of application.

CARE OF LUBRICATION SYSTEMS

The hand book of instructions accompanying each engine states the grade of lubricant to be used in each of the various systems. Ordinarily the crankcase oil is changed every 20 hours. The oil must be drained

while the engine is hot and the oil flowing freely in order to remove as much sediment as possible. At the same time the oil screen, or filters, must be cleaned.

TROUBLES

Overheating: This may be caused by:—

(a) Insufficient oil resulting in a more rapid circulation and consequent rise in temperature.

Low oil, in turn, may be caused by:

- (i) Negligence.
- (ii) A leak in the oil line (the observant pilot will usually spot this through the excess of oil thrown about the plane).
- (iii) Loss of oil through worn cylinder and scraper rings.

(b) Using a poor grade of oil: from inferior oil one may expect:—

- (i) Thinning or loss of viscosity, resulting in internal friction, heat and loss of power.
- (ii) Sludge formation with results much the same as above and the added evil of sludge plugging the screens and oil lines.
- (iii) An accumulation of carbon ash in the combustion chamber, causing pre-ignition.
- (iv) Sticking of valves and resistance in moving parts due to the presence of gum.

(c) Choked strainer, caused by:—

- (i) Negligence.
- (ii) Sludge formation.
- (iii) Accumulation of sediment due to the use of inferior oil.
- (iv) Moisture due to condensation particularly in cold weather.

Loss of Power or "Revs"

Loss of power is frequently associated with poor lubrication through:

- (i) Added friction in the moving parts.
- (ii) Loss of compression through improper sealing of the piston ring.

Low Oil Pressure

This may be caused by:—

- (i) Faulty gauge.
- (ii) Clogged strainer.
- (iii) Leak in the oil line.
- (iv) Frozen lead from pump to gauge.
- (v) Sticking by-pass valve.

If the flow of oil through the system is actually impeded as in (ii) and (iii), a drop in revolutions and rise in temperature will be quickly apparent.

ENGINE FAULT FINDING TABLE

(*For Light Aircraft*)

ON THE GROUND

Defect	Probable Cause	Detected by	Remedy
Engine does not start.	(*a*) Fuel turned off.	No gas in evidence.	
	(*b*) (Insufficient priming.		Choke by hand etc.
	(*c*) Flooding.	Strong odor: gas running from carburettor.	Swing prop. back and start afresh.
	(*d*) Engine cold.	Prop. hard to turn.	Heat oil and engine.
	(*e*) Poor quality fuel.		Drain and replace.
	(*f*) Defective plugs.	Plugs oil-soaked.	Examine and clean.
	(*g*) Sticking impulse.	No "click" from impulse.	Clean with parafine oil.
	(*h*) Defective breaker points.	Weak spark.	Clean and set.
Irregular running after starting.	(*a*) Dirty plugs.	Oil on electrodes.	Clean.
	(*b*) Air leak in induction pipe.		
	(*c*) Broken valve-spring.		
	(*d*) Corrosion in heater box.		
	(*e*) Altitude control open.		
Engine has regular miss.	(*a*) Defective plugs.	Affected cylinder cool to touch.	
	(*b*) Crack in cylinderhead.	Hissing explosion. Strong odor.	
	(*c*) Sticking valve.	Distinct knock or squeak.	
Engine backfires on starting.	(*a*) Mix. too lean		Adjust carburettor.
	(*b*) Sticking inlet valve.	Resistence to turning prop.	Oil or repair.
	(*c*) H. T. Leads crossed.	Examine wiring.	Re-assemble.
	(*d*) Spark too far advanced.	Examine spark lever —if any.	Adjust timing.
	(*e*) Hot electrode or carbon in cylinder.	Hot engine.	Permit to cool.

ENGINE FAULT FINDING TABLE—*Continued*

(*For Light Aircraft*)

ON THE GROUND

Defect	Probable Cause	Detected by	Remedy
Engine backfires on starting.	(*f*) Sticking float needle; or toggles. Collar displaced.	Restricted or uneven flow of gas.	Drain system. Examine parts and repair.
	(*g*) Air lock in fuel pipe. Dirt or water in carburettor.		As above.
Loss of Power. (on ground).	(*a*) Dirty plugs.		
	(*b*) Poor compression:— (i) Wrong valve clearances. (ii) Worn valve seats. (iii) Worn piston rings.	Uneven resistence in turning engine by hand.	Replace or repair.
	(*c*) Faulty synchronization of mags.	Drop in revs. with one switch cut.	Re-Time.
	(*d*) Carbon in head.	Carbon knock.	
	(*e*) Weak spark.	Defective magneto.	Repair or replace.
	(*f*) Poor fuel.	Overheating.	Drain and replace.
	(*g*) Weak mix.	Overheating.	Adjust.
	(*h*) Faulty lubrication.	Overheating.	Examine system and correct.

ENGINE FAULT FINDING TABLE

IN THE AIR

Defect	Probable Cause	Detected by:—	Remedy
Engine Stops.	(*a*) Lack of fuel:— (i) Throttle closed. (ii) Gas turned off. (iii) Supply exhausted. (*b*) Switches knocked off. (c) Overheating due to:— (i) Faulty lubrication. (ii) Internal friction. (*d*) Mechanical failure e.g. broken connecting-rod.	 Position of throttle lever. Position of gas control. Position of gauges. Position of switches. Low oil pressure and overheating. Overheating. Loud knock and vibration.	 Open lever. Open lever. Shut-off and land.
Engine loses power in the air.	(*a*) Overheating, due to:— (i) Poor or insufficient oil. (ii) Lean mix. (iii) Rich mix. (*b*) Incorrect valve clearance. (c) Improper use of altitude control. (*d*) Internal friction.		
Engine runs rough.	(*a*) Prop. out of balance. (*b*) Engine bearers loose. (c) Mix. too rich. (*d*) Sticking valve. (*e*) Pre-ignition. (*f*) Wrong valve clearances.		
Engine continues to run with switches off.	(*a*) Defective switch or wiring. (*b*) Pre-ignition and overheating.		
Engine will not take throttle.	Mix. too lean. Engine cold.	Enrich mix. Frequent bursts.	

WINTER OPERATION

Winter flying in Canada requires special care of the lubricating systems. As a matter of routine the following operations must be carried out when the cold weather is upon us:—

(i) Change to a lighter oil.

(ii) Lag the external oil lines and tank in a dry sump system.

Where operations are carried out from an unheated hangar it is good practice to drain the oil while the engine is hot at the end of each day's operations. The drained oil must be kept in a clean and carefully sealed container. The practice of putting the oil in an open bucket and permitting dust, dirt and ashes to settle into it at will must not be tolerated. The oil should be stored in a warm room and before return to the engine should be heated in a pan of hot water or some similar device. If the oil is placed near a stove the greatest care must be exercised to see that it is uniformly heated, as the application of extreme heat to one spot may break down the body of the oil and destroy its lubricating properties.

(iii) **Cowling.**—Sometimes in order to maintain the correct operating temperature it is necessary to modify the cowling in order to retain more heat in the engine.

SUMMER OPERATION

The pilot must know the ordinary operating temperature of his engine and the maximum temperature permissible. Students should practice converting temperature readings on the Centigrade scale to Fahrenheit and vice versa.

Remember:—

Fahrenheit to centigrade.—subtract 32 and multiply by $\frac{5}{9}$.

Centigrade to fahrenheit.—multiply by $\frac{9}{5}$ and add 32.

The use of a diagram in explaining the oiling system has been greatly over-rated: to achieve anything worthwhile the student must have before him the bottom half of a crankcase containing pump, oil lines, galleries, crankshaft with bearing caps removed and one connecting rod attached.

In this way it will be easy for him to follow the flow of the oil in the pressure system from the sump, through the screen to the pump. The release valve and by-pass should be dismantled and shown to him. The flow of oil should be traced from the pump to the gallery (Gipsy) and thence to the crankshaft main bearings and con. rod bearings. From this it will be easy for him to visualize the effect of splash and his attention should be drawn to the oil ports in camshaft and timing bearings in order to admit the splashed oil.

The method of forcing grease into the rocker-arm bearings and dropping oil into the magneto armature bearings should also be explained to him.

Inspection:—The following points must be observed.

(I) External oil lines and joints.

(II) Hose connections.

(III) Quantity of oil in tanks.

(IV) Filter cap secure.

(V) Union nuts locked.

QUESTIONS ON ENGINES

1. What is meant by "compression ratio"?
2. If a plug gives a good spark in the open will it necessarily operate satisfactorily in the engine?
3. What are the common causes of pre-ignition?
4. Give five common causes of rough running of an engine.
5. One cylinder on your engine is missing. Give four probable causes; describe an easy method of discovering which cylinder is giving the trouble.
6. Briefly describe the oiling systems in use in your engine. State operating pressures and oil consumption.
7. Give six causes for an engine over-heating.
8. State, in the order of their probability, eight causes for an aeroplane engine being difficult to start. Give the steps you would take to remedy one of them.

Reference for engines and rigging:—

Flying Training Manual Part I.

Dyke's Aircraft Engine Encyclopaedia.

AIR PILOTAGE

Treated under the following headings:—

(I) Definitions. General features of maps and charts.

(II) Navigation instruments.

(III) Practical course plotting.

(IV) Compass swinging.

DEFINITIONS AND GENERAL FEATURES OF MAPS AND CHARTS

Lesson No. 1

Air Navigation — is the art of conducting an aircraft from place to place when out of sight of land, by observations of celestial bodies.

Air Speed — is the speed of an aircraft relative to the air.

Axis of the Earth — is that diameter about which it revolves.

Bearing — the angle between a meridian passing through the observer and the point observed. This is measured from zero at the north to the right through 360 degrees. This is spoken of as a true bearing when the meridian is a true meridian.

Magnetic Bearing — the bearing is referred to as a magnetic bearing when the angle is measured from a magnetic meridian.

Contour — the representation on a map of an imaginary line running along the surface of the ground at the same height above sea-level throughout its length.

Course:—

(i) the **true course** is the angle between the longitudinal axis of an aircraft and the true meridian.

(ii) the **magnetic course** is the angle between the longitudinal axis of an aircraft and the magnetic meridian.

(iii) the **compass course** is the angle between the longitudinal axis of an aircraft and the direction of a particular compass needle.

Dead Reckoning — consists in calculating the track and ground speed of an aircraft. **D.R. position** is the position arrived at by dead reckoning.

Deviation — is the angle between the magnetic meridian and the direction of a particular compass needle influenced by a magnetic field not coincident with the earth's magnetic field. It is named East (+) or West (−) according to whether the north-seeking pole lies eastward or westward of the meridian.

Dip — of a magnetic needle is the angle in the vertical plane between the horizontal and the direction of the earth's line of total magnetic force, sometimes called **magnetic inclination.**

Equator of the Earth is the great circle of which the plane is at right angles to the axis.

Great Circle — is a circle on the surface of a sphere the plane of which passes through the centre of the sphere and thus divides it into two equal parts. The shortest distance between any two points on the surface of a sphere is the arc of a great circle joining the points.

Ground speed — is the speed of an aircraft relative to the ground.

Hachuring — is a convenient method of representing hill features by shading in short disconnected lines, which are drawn approximately down the slopes in the directions in which water would flow.

Horizontal Equivalent — the distance in plan between two adjacent contours. (Written H.E.).

Knot—is a unit of speed: it equals a speed of one nautical mile an hour.

Latitude of a place is the arc of the meridian between the equator and the place and is named N. or S., in accordance as the place is N. or S. of the equator.

A Parallel of Latitude is a small circle parallel to the Equator.

Difference of Latitude between two places is the arc of a meridian intercepted between the parallels of the places. (Written d. Lat.).

Longitude of a place is the smaller arc of the equator intercepted between the prime meridian and the meridian of the place.

Difference of Longitude of two places is the smaller arc of the equator intercepted by their meridians. (Written d. Long.).

Magnetic Meridian — the great circle on the earth at any place in the plane of which a magnetic needle would lie, if freely suspended and influenced only by the earth's magnetic field.

Magnetic Poles of the earth are the two positions where the earth's line of total force is vertical, and towards which, in all adjoining regions, the compass needle points.

Meridian is a semi-great circle passing through the poles of the earth.

The Prime Meridian is that one from which longitude is measured. The meridian of Greenwich is accepted as the prime meridian by most countries.

Nautical Mile is the average length of a minute of latitude measured on any meridian. Its length is generally taken as 6,080 feet.

Orienting a map is the process of setting it so that the North line on the map points North.

Poles of the earth are the extremities of its axis of revolution.

Position Line is a line obtained from observation of a terrestrial object or a celestial body somewhere on which line it is known the aircraft must be.

Projection of a map or chart is any orderly system of representing meridians and parallels and the earth's surface on a plane.

Representative Fraction — the ratio which the distance between two points on a map bears to the distance between the same two points on the ground. The ratio is always expressed as a vulgar fraction, of which the numerator is unity. It may also be called the **natural scale.**

Rhumb Line is that curve on the earth's surface which cuts all the meridians it meets at the same angle. The equator and all parallels of latitude are rhumb lines.

Small Circle is a circle on the surface of a sphere of which the plane does not pass through the centre of the sphere.

Spot Height — the record on a map of the exact height of a particular point above sea level.

Track is the angle contained between a meridian and a line representing the actual path of an aircraft relative to the earth. It may be referred to the true or the magnetic meridian.

Variation (or Declination) is the horizontal angle between the vertical plane of the true meridian and the vertical plane passing through the axis of a freely suspended magnetic needle resting in the earth's line of total magnetic force. It is named East (+) or West (−) according to whether the north-seeking end of the needle lies eastward or westward of the true meridian.

Vertical Interval — the difference in level between two adjacent contours. (Written V.I.).

Air Pilotage — the subject of PILOTAGE may be roughly defined as the science of finding one's way by air to a desired destination. Leaving out of account the fixing of a position by observation on celestial bodies called Navigation, Pilotage comes under two general headings:—

(a) Finding one's way by ground observation and map reading.

(b) Flying by dead reckoning. This implies the calculating of the desired course from reference to maps before leaving the ground, together with the necessary corrections in the air, and, maintaining that course by means of the magnetic compass. From the above it will be seen that the successful pilot must have —

  (I) A thorough understanding of maps and,

  (II) A thorough understanding of the magnetic compass.

MAP PROJECTIONS

A map is an attempt to show on a plane surface, such as a piece of paper, a certain section of the earth's surface. The earth's surface, however, is rounded and can never be accurately shown on a flat surface. In map making, four general points have to be considered. They are:—

(I) Land shapes.

(II) Areas.

(III) Angles.

(IV) Distances.

The pilot is concerned only with the last two.

At present we shall concern ourselves only with two types of map projections, i.e., Mercator's and the Polyconic projection.

Mercator's Projection — the Mercator's projection is frequently used in the preparation of marine charts. Its characteristics are as follows:

(i) Meridians are parallel straight lines.

(ii) Lines of Latitude are parallel straight lines.

(iii) The parallels of latitude constantly increase in distance from the equator toward the poles, e.g., the distance from equator (0) to Lat. 15° as shown on the map is only about half the distance between Lat. 60° and Lat. 75°.

(iv) No scale then can be shown on a map made on a Mercator's projection.

(v) Distances must be measured by referring to the degrees of latitude shown on the sides of the map (1 minute of latitude equals 1 nautical mile) **immediately** opposite to the line to be measured. This is generally spoken of as taking the mid-latitude distance.

(vi) Bearings are accurately measured directly from the meridians.

(vii) The nearer one approaches the poles the more exaggerated in size the land areas become.

(viii) A rhumb line bearing is shown by a straight line on the map.

(ix) A Great Circle bearing is shown by a curved line on the map.

From the foregoing, two points of importance to the pilot appear i.e.:

(i) Angles or bearings may be accurately measured from any meridian.

(ii) Distances **must** be measured from the latitude distance opposite the middle of the course to be measured. This distance will be taken in nautical miles and converted to statute miles. 1 Nautical mile = 6080 feet or — Statute mile is to Nautical mile as 66 is to 76 approximately.

Polyconic Projection — there are numerous variations of the polyconic projection but the following characteristics may be taken as applying to all of them in a general way.

(i) The meridians are straight lines.

continuously over a very large area, such as the whole of Canada. They may, however, be extended continuously over a comparatively narrow strip of country, which may be unlimited in length. The squares appearing on the maps issued by the Topographical and Air Survey Bureau have been designed to cover a strip of country some 350 to 400 miles wide in an east-west direction, and unlimited in length towards the north. These squares are numbered continuously from the south to the north, and from the west to the east, the numbers appearing in the borders of the map.

In the settled parts of the Prairie Provinces, however, where it is necessary to show the outlines of the Dominion Lands System of townships, the grid squares are not shown in full on the map, because they would be confused with the township outlines; but their positions are indicated by ticks in the borders of the map. These ticks enable the squares or grid lines to be drawn by anyone who wishes to use them.

The squares serve several purposes. First, the fact of the map being divided into four-mile squares helps the map-reader to estimate distances. Secondly, the numbers of the squares can be used to designate the location of a point; thus we may refer to an un-named lake shown on the map as lying in Square 139-42. For new areas where the topographical features are not yet named, this method of map reference is a great convenience. Thirdly, the squares provide a ready means for calculating the distance and bearing between any two points in the same strip of country.

As an example of this latter quality, we may compute the distance between, say, Winnipeg seaport on the Red river and some point, such as the Norway House post in northern Manitoba. The position of the Winnipeg seaport is shown on the Winnipeg sheet, and that of the Norway House post is shown on the Norway House sheet. These map sheets show the township outlines; the positions of the grid lines being indicated only by ticks in the map borders. If the necessary grid lines are drawn by joining corresponding ticks in the opposite margins, it will be seen that the Winnipeg seaport lies in Square 253−86, and Norway House lies in square 324−75. This means that approximately Norway House is 324−253=71 squares = 284 miles north, and 86 − 75 = 11 squares = 44 miles west of Winnipeg seaport. By squaring and adding, and then taking the square-root, we can get the approximate distance between the two places. If we want the distances accurately, we must measure the distances of Winnipeg seaport and Norway House in their particular squares — measuring always from the southwest corner of each square, since the squares are numbered from the south and west. We thus get the co-ordinates of the two points. These are:—

Winnipeg seaport	N.	253.74	E.	86.39
Norway House	N.	324.44	E.	75.42
Difference		70.70		10.97

In making a cross country flight it is wise to look carefully over the map of the country across which you propose to fly and ascertain the altitude at which you will have to fly to clear the hill tops. It is good practice to know the elevation of the aerodrome at which you expect to land.

NAVIGATION INSTRUMENTS

Lesson No. 2

The instruments used in air pilotage are:—

(i) Magnetic compass.

(ii) Airspeed indicator.

(iii) Altimeter.

(iv) Clock or chronometer.

(v) Bank and Turn indicator.

(vi) Pitch indicator (not in general use).

Other instruments are used in more advanced methods of navigation but they cannot be touched upon here.

THE MAGNETIC COMPASS

The P. 4 compass of British manufacture is probably in most general use in this country and the following notes will have reference to it.

Parts: (i) **Magnets.** These are two in number and are given a pendulous mounting well below the pivot or point of support. This gives the magnets good inherent stability in a vertical plane and automatically makes the necessary correction for magnetic dip which, in this latitude, is about 60°.

Bowl: This contains the alcohol. Its chief features are:—

(a) A flexible expansion chamber to take care of expansion due to change of temperature.

(b) Glass plate in the top of the bowl.

(c) The pivot on which the magnets are suspended.

(d) The magnets.

(e) The damping filaments which offer resistance to the rapid turning of the magnets in the liquid and practically eliminate oscillation or swinging back and forth of the needle.

(f) Verge ring.

(g) Sponge rubber mounting. This prevents the bowl from coming into metallic contact with any part of the aircraft. Should such a contact be made the resultant vibration would render the compass almost useless.

(h) Lubber line; this is a needle or pointer protruding into the bowl. It must be set in the fore and aft line of the plane or parallel to it.

(i) Mounting: this must be made of non-magnetic material.

The student is recommended to practice making these conversions from one form to another until he becomes thoroughly familiar with the process.

FLYING BY COMPASS

The centre of gravity of a compass needle in this latitude is well south of the point of support. In plain language, the south end is heavier than the north. Without going into the details of turning and acceleration errors, the following points should be noted for practical navigation:—

(I) While flying by compass always make a change of course with as gentle a turn as possible and with the minimum amount of bank. A steeply banked turn may be depended upon to render the compass useless for some minutes.

(II) Do not depend on your compass while increasing or decreasing your speed or in the commencement of a steep climb or glide while flying on an easterly or westerly course.

AIRSPEED INDICATOR

The following points are of interest in using the airspeed indicator:—

(I) It needs to be checked frequently for accuracy. A simple method on light aircraft is to stall the aircraft at a height and note the reading at the stalling point. If sticking, or highly inaccurate, an instrument must be taken out and corrected, especially for student flying.

(II) It is necessary to add about 1.75% to the indicated reading per thousand feet of altitude to obtain the correct airspeed.

(III) There is a lag of some seconds between the actual speed of the aeroplane and the reading on the dial in the advent of an abrupt change of speed i.e., the plane is stalled before the indicator shows stalling speed.

ALTIMETER

(I) Should be set at zero on the aerodrome from which you are operating.

(II) Needs watching, since the dial occasionally vibrates out of place.

(III) The reading lags appreciably in a steep dive or spin.

FURTHER NOTES ON AIR PILOTAGE

Latitude and Longitude — The position of any point on the surface of the earth may be defined by the latitude and longitude of the point. Latitude is measured from 0° to 90° N. or S. of the equator along a meridian and is expressed in degrees (°), minutes ('), seconds ("). Longitude is measured from 0° to 180° E. or W. of the prime meridian along the equator and is also expressed in degrees, minutes and seconds. English maps and charts are always constructed with reference to the meridian passing through Greenwich as the prime meridian but this is not universal for all foreign maps.

Bearing from A to B is 350° Mag., Variation 14° 45' E., in 1918, increasing 12' annually. What is the true bearing 1927?

Variation (1918)	14° 45' E.
Increase (12' × 9)	1° 48'
Variation (1927)	16° 33' E.
Mag. Bearing 350°	350°
Variation	16° 33' E.
	366° 33'
Subtract:—	360° 00'
True Bearing	6° 33'

EXAMPLES AND EXERCISES

Deviations, if named plus or minus, may be regarded as corrections to the compass course.

Magnetic	Compass	Deviation
0° (360°)	348° plus	12° E.
263°	278° minus	15° W.

The deviation card now in common use does not directly record the remaining deviation, but instead, it shows the compass courses to steer to make good the eight magnetic courses, N, NE, E, SE, S, SW, W, NW. There is space at the side of the card in which the deviations may be written if required. It is very often necessary to obtain the deviation for a course other than the eight recorded. This may be done by interpolation.

e.g. Deviation on 90° Mag. is plus 5°.
Deviation on 135° Mag. is plus 2°.

Required the compass course corresponding to a magnetic course of 108°.

Change of deviation from 90° to 108° $= \frac{18}{45}$ of 3° = 1° approx.

Deviation on magnetic course of 108° = plus 4°

Compass Course is 104°

In order to correct a bearing compass for deviation it is necessary to apply to it the deviation on the course of the aircraft at the instant the bearing is taken.

Examples:—

(1) What is the compass course corresponding to a true course of 205°? Variation 12° E. Deviation −3° W.

True Course	205°
Variation	12° E.
Magnetic Course	193°
Deviation	−3° W.
Compass Course	196°

If it were required to fly from a place in the north of Scotland to a point 500 miles away to the east on the same parallel of latitude the initial course set to fly on a great circle would be 83° T. and this course would have to be changed about 1° every 35 miles, until the final course was 97° T. The rhumb line track would be along the parallel and the course steered 90° T. for the whole journey.

The saving in distance would be less than a mile. Thus, for flights within the range of present day aircraft the difference between the great circle distance and rhumb line distance is negligible. There is no question that the rhumb line track is greatly to be preferred to the great circle track for all ordinary purposes in flying.

Distances which are too great to be measured accurately by means of a scale may be calculated mathematically. The following units of linear measure are in common use:—

(a) **Statute mile** — an arbitrary length which is adopted as standard in the British Empire and U.S.A. It equals 5280 feet. Abbreviation: m.

(b) **Nautical mile** — the average length of a minute of latitude measured on any meridian. It is most universally accepted as 6080 feet. Symbol (').

(c) **Cable** — one tenth of a nautical mile. Its length is generally taken as 600 feet.

(d) **Fathom** — 6 feet. Depth on charts are generally expressed in terms of this unit.

(e) **Kilometer** — the average length of one ten thousandth part of a quadrant of a meridian. Its approximate length is 3280 feet. Abbreviation: Km.

66 nautical miles equals 76 statute miles. 41 statute miles equals 66 kilometers. 41 nautical miles equals 76 kilometers. 5 statute miles equals 8 kilometers approximately.

PRACTICAL COURSE PLOTTING

Lesson No. 3

WIND AND DRIFT PROBLEMS

Composition of Velocities — The velocity of a body is the rate of change of position of a body in a given direction, so that it involves both speed and direction. Any velocity may conveniently be represented by a straight line. By employing a suitable scale the speed may be represented by the length of the line and by using a suitable reference line the direction may be shown relatively to that line. In the wind and drift problem which will be dealt with, the reference line normally employed is the true

charged with electricity and the exceptional changes in temperature in the interior are responsible for violent disturbances. It is always associated with thunder and lightning, hail, rain and snow, and should be absolutely avoided by aviators. The interior turbulence pays no respect to aircraft and it is known that upward currents reach hurricane force.

Approximate height from 4,000 to 25,000 feet to the summit.

Nimbus (Nb): the rain cloud. A dark shapeless mass of low lying cloud usually covering the entire sky from which steady rain or snow falls. Approximate height below 4,000 feet.

Fracto-Nimbus (Fr-Nb): generally known as "scud" and usually seen after steady rain when the sky begins to break. Moves swiftly below the main masses. Approximate height below 2,000 feet.

Stratus (St): a grey, rather shapeless layer of very low lying cloud looking more like an elevated fog, which it actually is. Seen often on early summer mornings resting just above the tree tops or in valleys and disappearing when the sun rises, to form cumulus or to be blown away as fracto-stratus. Approximate height below 2,000 feet.

THUNDERSTORMS

To produce thunderstorms, three important conditions must prevail, viz:—A good supply of water vapour must exist in the lower air, the surface air must be relatively warm and the upper air cold, or relatively so. In fact, the greater the difference in temperature between the surface and the upper air, the greater the tendency for thunderstorms, providing the lower air contains sufficient moisture.

Thunderstorms of the heat type occur when, owing to prolonged sunshine, the layers of air near the surface get sufficiently heated relative to the upper air, to bring about convection necessary for the development of thundery conditions. In all cases sufficient moisture must be available in the rising air.

When a large difference of temperature exists between the lower and upper air, the lower air being warmer, convection occurs and the rising air carries the water along with it. As the air rises it expands, owing to the fact that pressure decreases with altitude, and this expansion results in cooling. If the cooling be sufficient, the water vapour previously invisible, will condense and become visible as a cloud, and the condensation may be sufficient to cause rain.

The ordinary cumulus is brought about by convection, but very intense convection is necessary to produce the cumulo-nimbus cloud, or thundercloud. The fully developed cumulo-nimbus reaches tremendous dimensions, the base usually forming at about 4,000 feet while the apex frequently reaches 25,000 feet with false cirrus on the top giving it an anvil appearance. When the water vapour condenses to form a water

drop, this drop has naturally a tendency to fall, but the rising column of air may be ascending too rapidly, in fact, the drop may be held in suspension, or even carried upwards. The larger the raindrop, the more rapidly will it tend to fall. Drops larger than a certain size, however, become distorted in falling and break up into smaller drops. The largest raindrop possible is about a quarter of an inch in diameter, and this would fall, relatively to the air, at a speed of 17 m.p.h.

Thus, we see that if the velocity of the rising air is equal to, or exceeds 17 m.p.h., no rain can fall to the ground, and in the latter case it will actually be carried upwards. In the turbulent rising air of a thunderstorm, the large raindrops may be broken up into smaller drops, while these smaller drops may join together to form larger ones, and the process may be repeated while the turbulence lasts.

To return to the discussion on precipitation, some of the water particles will be carried upward with the ascending air to such an altitude that they will become frozen. These particles will rapidly increase in size by moisture being deposited on them in the supersaturated air. Thus, the hailstone is formed. Naturally the hailstone will tend to fall, but owing to the turbulence, the hailstone may be carried up again, and each journey will result in another coating of ice; finally it becomes so heavy that it overcomes the rising currents. Some idea of the magnitude of these currents can be gained by the sizes of the hailstones which are able to force their way to earth. It is estimated that the vertical currents in a well developed thundercloud can at times reach or even exceed gale velocity.

On May 8th, 1926, at Dallas, Texas, during a severe thunderstorm, hailstones 2½ inches in diameter are reported to have fallen. In the region of a thundercloud the terminal velocities for various sizes of hailstones are as follows:—

½ inch in diameter	— 36 m.p.h.
1 inch in diameter	— 51 m.p.h.
1½ inches in diameter	— 63 m.p.h.
2 inches in diameter	— 71 m.p.h.
3 inches in diameter	— 90 m.p.h.

It is certain, therefore, that the vertical currents associated with the exceptionally severe storm at Dallas must have reached about 80 m.p.h.

WINTER OPERATION

Winter flying in Canada requires special care of the lubricating systems. As a matter of routine the following operations must be carried out when the cold weather is upon us:—

(i) Change to a lighter oil.

(ii) Lag the external oil lines and tank in a dry sump system.

Where operations are carried out from an unheated hangar it is good practice to drain the oil while the engine is hot at the end of each day's operations. The drained oil must be kept in a clean and carefully sealed container. The practice of putting the oil in an open bucket and permitting dust, dirt and ashes to settle into it at will must not be tolerated. The oil should be stored in a warm room and before return to the engine should be heated in a pan of hot water or some similar device. If the oil is placed near a stove the greatest care must be exercised to see that it is uniformly heated, as the application of extreme heat to one spot may break down the body of the oil and destroy its lubricating properties.

(iii) **Cowling.**—Sometimes in order to maintain the correct operating temperature it is necessary to modify the cowling in order to retain more heat in the engine.

SUMMER OPERATION

The pilot must know the ordinary operating temperature of his engine and the maximum temperature permissible. Students should practice converting temperature readings on the Centigrade scale to Fahrenheit and vice versa.

Remember:—

Fahrenheit to centigrade.—subtract 32 and multiply by $\frac{5}{9}$.

Centigrade to fahrenheit.—multiply by $\frac{9}{5}$ and add 32.

The use of a diagram in explaining the oiling system has been greatly over-rated: to achieve anything worthwhile the student must have before him the bottom half of a crankcase containing pump, oil lines, galleries, crankshaft with bearing caps removed and one connecting rod attached.

In this way it will be easy for him to follow the flow of the oil in the pressure system from the sump, through the screen to the pump. The release valve and by-pass should be dismantled and shown to him. The flow of oil should be traced from the pump to the gallery (Gipsy) and thence to the crankshaft main bearings and con. rod bearings. From this it will be easy for him to visualize the effect of splash and his attention should be drawn to the oil ports in camshaft and timing bearings in order to admit the splashed oil.

The method of forcing grease into the rocker-arm bearings and dropping oil into the magneto armature bearings should also be explained to him.

4. The ground speed.
5. The direction of the wind.
6. The speed of the wind.

A knowledge of any four of these is sufficient to complete the triangle from which the remaining quantities may be determined. Problem 1: To determine the course to steer to make good a given track and ground speed, knowing the direction of the wind and the air speed of the aircraft.

Example — Aircraft is to proceed from A to B.

Track from A to B NE.

Air speed of aircraft 80 miles per hour.

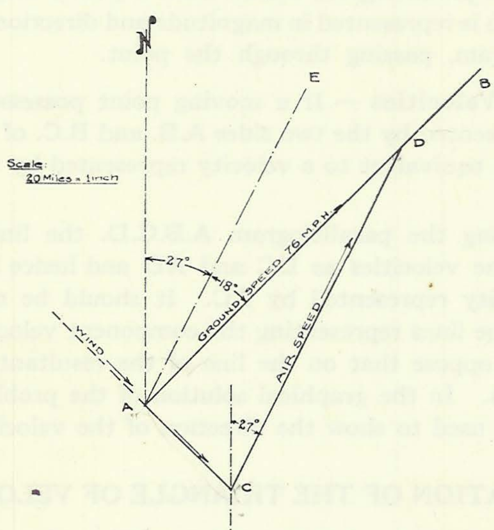
Wind NW 25 miles per hour.

The direction from which the wind blows is always given.

Required: the course to steer and ground speed.

Draw AB in direction NE to represent the track. Fig. 1.

FIG. 1



From A draw AC in direction 135° (i.e. down wind) length 25 mph. to represent the wind.

With C as centre and scale length representing 80 mph as radius describe an arc cutting AB in D.

Join CD.

Then in the triangle ACD, AC represents the wind in speed and direction. CD represents the course and air speed, and AD represents the track and ground speed.

From A draw AE parallel to CD.

The course to steer is the angle CD makes with the meridian which equals the angle NAE — 27° (true).

To find your position on a map from observations on two points on the ground:

(i) Locate the points observed on the map.

(ii) From each of these points lay off reverse bearings (plus or minus 180°) to the ones you have made, e.g. if your observed bearings were 45° and 320° then your reversed bearings would be $45° + 180° = 225°$ and $320° - 180° = 140°$. The point of intersection of these two lines will give your position on the map.

(iii) To find your latitude position:

(a) Measure north from the nearest parallel of latitude, taking the proportional distance between it and the next parallel north; e.g. you are ⅔ of the way north between 49° 30' and 49° 45'; the distance between these lines is 15'; you are therefore ⅔ of $15' = 10$ minutes north of 49° 30', i.e., 49° 40' north.

(iv) Measure west from the nearest meridian, taking the proportional distance between it and the nearest meridian west e.g., if you are half way between 79° 0' and 79° 15' W, your position would obviously be 79° 7' 30".

To establish a compass course while in the air:

The two-point method—

(i) Draw your desired track on the map before leaving the ground.

(ii) Observe the map carefully and note two prominent land marks either on the track or parallel and near to it.

(iii) When you have reached your desired height fly to a position well back from the two points and fly toward them, manoeuvring in such a way as to keep in line with the two points.

(iv) When you have settled into a position that is carrying you straight along your track note your compass reading or set your verge ring. This will be the correct compass course for the desired track.

The 10 Degree Method:—

(i) Draw your desired track on the map before leaving the ground.

(ii) Look for a prominent line such as a railway, road or river crossing your track as nearly as possible at a right angle and not more than ten or fifteen minutes away from your base.

(iii) Measure the distance to this line and, taking into account your airspeed, calculate the time it will take you to reach it.

(iv) Centre a protractor on your home base and lay off two or three lines at intervals of 10° from your track on each side of it. Mark on the map the points where these intersect with your selected line.

(v) Let us assume that the line you have selected is 12 minutes of time away from your base. At the end of 12 minutes flying you find yourself to the left of your track about ¾ of the way toward the

far can you get along AB in one hour at 80 mph starting from C? We take a line equal to 80 mph in length and with centre C describe an arc cutting AB in D. AD, then, is the distance made good in one hour along the line AB. We measure this and find the distance to be equal to 76 mph. Your bearing is the angle between north and the line DC. This angle (342°) is measured from a meridian, or a line parallel to a meridian, completely around to the right.

Reference books:—

Manual of Air Pilotage.

QUESTIONS

(1) How would you recognize a map plotted on:
- (a) Mercator's projection?
- (b) Polyconic projection?
- (c) What precautions would you take in measuring angles and distances on each?

(2) How could you measure distances on a map showing latitude and longitude but no scale or R-F? How do you convert nautical miles to statute miles?

(3) The bearing of "B" from "A" is 80° T, and the distance 140 miles. The speed of your plane is 80 mph., wind 20 mph., from 330°, Var. 6° E. Show:
- (a) Compass bearing going and coming.
- (b) Speed going and coming.
- (c) Time going and coming.

(4) Describe two methods of establishing a compass course in the air after leaving the ground, without previous knowledge of either wind velocity or direction.

SWINGING AIRCRAFT FOR COMPASS ADJUSTMENT

Lesson No. 4

Object — The object of swinging an aircraft for compass adjustment is to reduce as far as possible any deviation on the compass needle, after which the corrected compass readings are tabulated for the information of the pilot or navigator.

Deviation — The compass depends for its action upon the fact that the earth is a magnet. The compass needle when under the influence of the earth's magnetism only takes up a certain position relative to true North, the vertical plane containing the line in which the needle then points being known as the magnetic meridian of that particular place. If the needle comes under the influence of magnetic forces additional to the natural forces of the earth, it will be deflected and no longer point in

Swinging Base — The operation of swinging is generally carried out on a swinging base taking the form of a large diameter concrete floor upon which the magnetic cardinal and quadrantal points are clearly and accurately marked. Such a base should have a level surface set at ground level, free from iron or steel in the foundations and situated at least 50 yards from any buildings or other objects likely to affect the compass needle; this distance should be increased to at least 100 yards if the building should be a generating or W/T station.

Procedure for Swinging — The aircraft is wheeled on to the base and adjusted until the machine points S. (Check by noting that the plumb-lines coincide with, or are parallel to, the N. and S. line marked on the base. A note is then made of the compass readings and the aircraft is turned to W. and the compass reading on this point noted. The operation is again repeated with the aircraft heading N. Having now found the compass readings of N. and S., it is possible to find the mean N. and S. deviation for the purpose of making the required correction; e.g., if the observed reading when heading S. (180°) was 169° the deviation at this point is 11°E (written + 11°) and if the observed reading when heading N. (360°) was 5° the deviation at this point is 5°W. (written −5°).

It should be noted that if the compass reading **is greater** than the magnetic reading the deviation is West; **if less**, the deviation is East.

This is easily remembered by the following:—

"When compass reads best deviation is West".

"When compass reads least deviation is East".

Westerly deviation is always written with a **minus** sign, **Easterly** deviation with a **plus** sign.

In the above example the deviation on N. is − 5° and on S. is + 11°. To find the mean deviation on these two points the sign in front of the deviation on S. is changed, and the two deviations are summed algebraically and divided by 2, the result being the mean deviation. The correcting of this error, so far as may be possible, is accomplished by placing one or more correcting magnets in the athwartship tubes of the corrector box. The number, strength and position of the magnets necessary to effect the required correction is a matter for trial.

The finding of the mean deviation as described above is shown below in tabular form:—

Magnetic Reading	Compass Reading	Deviation
N. 360°	5°	5°W. (− 5°)
S. 180°	169°	11°E. (+11°)

Changing the sign on the S. reading, then mean error is:—

$$\frac{-5-11}{2} = -\frac{16}{2} = -8°$$

The whole process may be summarized briefly as follows:—

1. Head aircraft S. take reading.
2. Head aircraft W. take reading.
3. Head aircraft N. take reading and correct as above.
4. Head aircraft E. take reading and correct as above.
5. Head aircraft S.E. take reading.
6. Head aircraft S. take reading.
7. Head aircraft S.W. take reading.
8. Head aircraft W. take reading.
9. Head aircraft N.W. take reading.
10. Head aircraft N. take reading.
11. Head aircraft N.E. take reading.
12. Find mean error and correct lubber line.
13. Correct deviation and fill in card.

The following are important points to remember:—

(a) Change sign of deviation on S. and W. to find mean deviation.

(b) Correct compass on N. and E. only.

(c) If mean error on E. is minus, place red end of magnets aft, if plus, red end forward.

(d) If mean error on N. is minus, place red end of magnets to port; if plus, red end starboard.

(e) If mean deviation on all 8 points is minus, move lubber line to port; if plus, to starboard.

METEOROLOGY

Treated under the following headings:—

(I) Definitions: Air Properties: Instruments: Clouds and Cloud Types

(II) Reading the weather chart.

(III) Practical hints concerning.—line squalls; ice formation; lowvisibility flying.

DEFINITIONS; AIR PROPERTIES; INSTRUMENTS; CLOUDS AND CLOUD TYPES

Lesson No. 1

INTRODUCTION

What is it moulds the life of Man?
The Weather!

What is it makes some black, some tan?
The Weather!

What makes the Zulus live in trees:
The Congo natives dress in leaves:
While others go in furs — and freeze?
The Weather!

There is no calling on earth to which weather means as much as it does to aviation. Rain, snow, fog, cloud, wind, heat, haze and hail all have a peculiar and vital significance to the pilot. Rapid steps are being taken to collect weather reports; classify them; predict tendencies, and place the results at the disposal of the flying fraternity. The purpose of this brief course is to give assistance in understanding these reports.

DEFINITIONS

Isobar — Line joining points of equal barometric pressure on a weather chart.

Isotherm — Points of equal temperature shown on a weather chart. Isothermal lines are lines joining these points. (Not usually shown on weather chart).

Relative Humidity — The ratio of the amount of moisture actually contained in the air at a given temperature to the greatest amount of moisture that the air will contain at that temperature. This is shown in terms of percentage, e.g., assuming that a cubic yard of air at a given temperature will contain one ounce of water vapour, and that the amount of water vapour actually present weighs only ½ ounce; then the relative humidity of that air is 50%.

Saturation Point — Had it contained one ounce the humidity would have been 100%. This is known too as the "saturation point", i.e., the point at which, for a given temperature the air can contain no more moisture.

Dew Point — This is the temperature to which the air must be cooled before the quantity of water vapour in it is sufficient to saturate it. Any further cooling of the air will cause it to give out its moisture in the form of dew.

AIR PROPERTIES

The following properties of air are of interest to the student of meteorology:

(i) Air has weight and exerts a pressure in all directions on everything it touches.

(ii) The pressure varies with:

(a) The elevation: air is denser and exerts more pressure at sea-level than at higher altitudes. The higher the altitude the less the pressure.

(b) The temperature. The higher the temperature the less the weight in free air.

(c) The humidity. The higher the humidity the less the pressure.

From this a number of things follow:

(iii) Heated air expands and, being light, rises.

(iv) As the hot air rises the colder and heavier air on its flanks moves in under it.

(v) As the hot air rises it expands and as it expands it cools. If the hot ascending air contains a large percentage of moisture, condensation may take place and clouds may be formed (common summer cumulus).

INSTRUMENTS

Barometer — The instrument used to measure air pressure is called a barometer. At a temperature of 60° Fah. at sea level, dry air pressure will support a column of mercury 29.92 inches in height in vacuum. For most purposes the aneroid barometer is used (it is an accordion-shaped metal container, from which most of the air has been expelled, acting against a spring).

Wet and Dry Bulb Thermometers — This consists of two similar thermometers set side by side. One of these has a wick kept constantly wet surrounding its bulb. When these are moved through the air the dry bulb gives a true temperature reading. If the air is dry, the wet bulb will give off moisture through evaporation. The temperature drops due to the evaporation and so a difference of temperature readings between the two thermometers will be shown. From this difference in reading the humidity may be calculated.

Wind Velocities — Are obtained in a number of ways the commonest being to observe the effect of the wind on surrounding objects and report it according to a recognized scale. The best known of these is the Beaufort scale.

CLOUDS

Clouds may be classified in four ways:—

(I) According to shape (round or cumulus; flat or stratus).

(II) Height at which they occur.

(III) Composition (water droplets or ice particles).

(IV) The manner in which they are formed. (By convection currents; by the superposition of a cold current of air over a warm moist one.)

CLASSIFICATION OF CLOUD TYPES

High — Cirrus, Cirro-Stratus, Cirro-Cumulus. Height 20,000 feet to 35,000 feet.

Medium — Alto-Cumulus, Alto-Stratus, Cumulo-Nimbus. Height 10,000 feet to 20,000 feet.

Low — Nimbus, Cumulus, Strato-Cumulus, Stratus. Height below 10,000 feet.

The main cloud types are CIRRUS, CUMULUS, NIMBUS, and STRATUS, and in different stages of transition they are preceded by a prefix. Clouds in the cirroform group are preceded by the prefix **Cirro**, which means that they are exceptionally high, approximately 30,000 feet.

The prefix **Alto** means high or height, approximately 15,000 feet; **Strato**, means layer or sheet, and **Fracto** means broken or detached.

Great care should be taken when classifying clouds, expecially when a prefix is necessary; for example, a Cirrus cloud is found at approximately 30,000 feet. It would be foolish to say Alto-Cirrus, because we already know that it is a high cloud; the same would apply to using Fracto-cirrus because cirrus is always broken and detached, except when it is stretched across the sky in a thin sheet when it is known as Cirro-stratus. In the case of nimbus, the rain cloud, which is a low cloud forming at approximately 2,000 feet, it will be readily understood why it should never be described as Alto-nimbus or cirro-nimbus.

For general forecasting clouds are of little use, but in many cases are useful for local prediction. For instance, the appearance of a liberal amount of cirrus usually means a depression within 48 hours, or, if the barometer is falling steadily, within 24 hours. If cirrus is followed by cirro-stratus and then alto-stratus it can be taken for granted that rain is not far away. Cirrus can also be seen after a depression but in this case it usually disappears leaving a blue sky.

Description of Cloud Types:—

Cirrus (Ci): a white, feathery, detached cloud of delicate wispy structure generally streaked across the sky as if a painter had made a sweep with his brush. Sometimes known as "mares' tails" or "cats' whiskers". Made up of ice crystals owing to their great height. Approximate height 25,000 to 35,000 feet.

Cirro-stratus (Ci-St): a thin layer of grey or white cloud; looks like a sheet spread across the sky. Milky and fibrous in appearance, showing the sun or moon through as a pale light. Produces approximate height 25,000 to 30,000 feet.

Cirro-Cumulus (Ci-Cu): sometimes known as a "mackerel sky". Consists of small rounded puffs of white cloud arranged in regular rows or groups. Resembles wavelets or white-caps. Approximate height 20,000 to 25,000 feet.

Alto-Stratus (A-St): similar in structure to cirro-stratus but is somewhat thicker and forms at lower levels. It is not so translucent as cirro-stratus but the sun or moon can be seen faintly through it. Dull days are associated with this type. Approximate height 10,000 to 20,000 feet.

Alto-Cumulus (A-Cu): similar in appearance to cirro-cumulus only the formation is larger and formation occurs at lower levels. The puffs are arranged in regular rows and groups sometimes converging in the centre. Approximate height 10,000 to 15,000 feet.

Cumulus (Cu): a white puffy cloud with hard edges, sometimes of massive dimensions with rounded towering tops like castles and turrets gleaming like silver in the sunlight while the base is flat and dark. Sometimes called the "cauliflower cloud" and resembles exploded cotton balls or ice-cream on a cone. Always seen in good weather, usually forming when the sun is at its height and disappearing in late afternoon. Approximate height 3,000 to 6,000 feet.

Fracto-Cumulus (Fr-Cu): cumulus torn or broken by high winds or mountain tops. Ragged and detached, but other characteristics similar to true cumulus. Approximate height 3,000 to 6,000 feet.

Strato-Cumulus (St-Cu): dull grey clouds looking like a mixture of nimbus and cumulus and usually covering the whole sky but broken irregularly. As the prefix implies, it stretches across the sky in a uniform layer. It can be distinguished from nimbus by its lumpy appearance and lack of precipitation. Approximate height 4,000 to 7,000 feet.

Cumulo-Nimbus (Cu-Nb): cumulo in this case is the prefix and the cloud itself is a mixture of cumulus and nimbus, a bad combination. Known also as the thunder cloud and resembles massive cumulus but is much greater in size sometimes having a base at 4,000 feet and a summit at above 25,000 feet, its approximate thickness being about 15,000 feet. Highly

READING THE WEATHER CHART

Lesson No. 2

The weather chart issued by the Meteorological Office in Toronto uses a number of symbols the significance of which must be understood before the chart can be read.

Wind direction is shown by arrows. The velocity is indicated by the number of barbs on the tail of the arrow on the Beaufort scale shown below.

Wind	Arrow	Speed m.p.h. above 30′	Speed m.p.h. ground 5′	Commonly observed effects of corresponding winds.
Calm	⊙	0	0	Smoke rises vertically.
Light Air		2	2	Direction of wind shown by drift but not by wind vanes.
Slight Breeze		5	4	Wind felt on face; leaves rustle, ordinary vane moved by wind.
Gentle Breeze		10	6	Leaves and small twigs in constant motion, wind extends light flag.
Moderate Wind		15	9	Raises dust and loose paper. Small branches are moved.
Fresh Wind		21	13	Small trees in leaf begin to sway, crest wavelets form on inland waters.
Strong Wind		27	18	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
High Wind		35	24	Whole trees in motion; inconvenience felt when walking against wind.

Symbols—Shaded areas show regions of precipitation during the past 24 hours. Small circles show the conditions overhead, as follows:

Clear .... ○
Partly cloudy .... ◐
Cloudy .... ●
Rain .... ®
Snow .... Ⓢ

CYCLONES AND ANTI-CYCLONES

Prominently shown on the weather chart are groups of more or less concentric circular lines marked "High" or "Low" in the centre. These are of great importance to the meteorologist. Experience has shown that the weather in these areas has certain well defined characteristics from which it is possible to forecast the weather probabilities over wide areas with fair accuracy.

CYCLONES

A cyclone is an area of low barometric pressure, or an area where the barometer is lower than the surrounding districts, sometimes referred to as a "depression" or simply a "low".

In accordance with Buys Ballot's Law, if you stand with your back to the wind in the northern hemisphere, the region of low barometric pressure is on your left hand and the high pressure is on your right, (this law is a necessary consequence of the earth's rotation). The direction of circulation in a cyclonic system in the Northern Hemisphere is anti-clockwise. The direction of the wind will, therefore, indicate the direction in which the cyclone lies. Hence a change of wind is very frequently a good indication of the centre of the depression. It is very difficult to predict accurately the direction in which the cyclone will move, but as a general rule they obey the following laws:—

Most lows affecting the lower lakes, and the Great Lakes regions are formed in the west, either in the western provinces or the middle western states, and move eastward to the Great Lakes and then on to the Maritimes. These lows are typical all the year round. Depressions appear to prefer the easiest path, i.e., over the sea, lakes or great waterway.

The movement of a depression can be followed and a fair estimate of the future course made. If readings be obtained from several other stations for the previous few days, a synoptic chart can be drawn and useful indications frequently obtained.

ANTI-CYCLONES

Anti-cyclones are characterized by calms or light winds, with fair, clear and bright weather and the appearance of Cumulus in the afternoon. If a high pressure is accompanied by fog, rain generally develops, but is of short duration. Indications that a high pressure is likely to remain for some time, till a fresh distribution of pressure takes place, are very hazy days with clear skies, or light winds and overcast skies. The appearance of Cirrus in most cases means the end of a high pressure, and the beginning of a low.

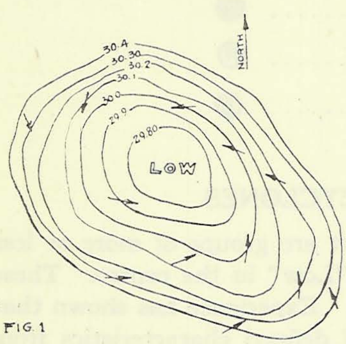


FIG. 1

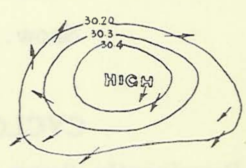


FIG. 2

WIND

We all know that water flows downhill and that some streams are sluggish and others swift:—in the former case they flow through country that has very little fall or gradient, and in the latter the fall is much greater or the gradient steeper, and the streams become roaring torrents. The same is true in the atmosphere and isobars are the lines that indicate the

levels in the air just as the contour lines indicate the levels on land; so if these isobars which are drawn usually for a difference of a tenth of an inch, are far apart the fall of pressure is very little or the gradient is gentle, and the winds, as one would expect, would be very light or almost calm as in fig. 2. Then if the isobars are close together the gradient becomes very steep and the winds will be very strong as shown in fig. 1. This relation is so very definite that if the steepness of the gradient is known the velocity of the wind can be calculated. These systems thus have very definite wind circulations connected with them. In fact, if the pressure distribution be charted, the associated winds in both direction and velocity can be added with fair accuracy without actually observing them.

READING THE WEATHER CHART

It has just been explained how the winds are related to the pressure system, but this is not all; it has been found that the temperature, clouds and rain are also closely connected with pressure distribution. All storms are associated with low pressure areas which are sometimes called cyclones on account of the winds appearing to revolve around them. The deeper the low pressure area, i.e., the steeper the pressure gradient, the more violent the storm, reaching the culminating point in the tornado on land, the hurricane of the West Indies, the cyclone of the Indian Ocean, and the typhoon of the China Sea; at the other extreme of the low pressure area is a central area with pressure very little lower than the surrounding regions in which case the gradients are slight, with little if any wind.

On studying chart, fig. 1, it will be noticed that the winds are southwesterly in the southern sector, southeasterly in the eastern sector, northeasterly in the northern, and northwesterly in the western sector. Now it is generally the southerly and easterly winds that produce clouds and especially rain. Both winds are on the eastern half of the low pressure area so that in general the rainy area is the eastern half of the lows, while northwesterly and westerly winds are usually associated with clearing weather and are in the western half of the lows. Then again, the weather is often sultry, muggy, moist and hot in summer or comparatively warm in winter with southerly winds; these are the conditions that are found in the southeastern quadrant. On the other hand, the cool, dry weather is associated with the westerly winds and found in the west quadrant.

The high pressure areas are regions of fine, clear, cool weather, with light winds. The extreme cold waves are associated with highs. In highs the gradients are always very slight and the region is one of calms. Thus, if the pressure distribution is known, the weather is also known for the region.

FORECASTING

So far we have been been examining the two pronounced types of pressure distribution and the weather associated with them, but before we can make any use of them it is necessary to see what happens to them from day to day. For this purpose weather maps of North America for

November 26, and 27, 1926, are reproduced in figs. 3 and 4. They show that on the 26th a very pronounced low was centred near Chicago with a high over the Canadian west and Atlantic coast. By the following morning the low had moved to the mouth of the St. Lawrence and the high had moved southeasterly. The shaded areas indicate regions where rain had fallen during the past 24 hours. It thus seems that these areas are great tourists, regular globe-trotters, and they exhibit all the types and varieties of the tourists; sometimes they linger until we long for them to pass, and again they rush by with the speed of an express train. Now, the forecaster's problem is to foresee what is going to happen with these pressure areas, how they are going to behave and what they are going to do, and where. If he can forecast these he can make an accurate prediction of what the weather will be, but they don't behave as expected sometimes. It may be the indications are for them to travel with a certain velocity in a certain direction, but instead they move at a different rate in a different direction, consequently the forecast is incorrect. The systems in figs. 3 and 4 are well defined, but they are not always so definite. In many cases the pressure is very uniform over most of the continent. There are many variations from the types given in these figures, and often distribution is ill-defined and irregular, but the main characteristics are always present.

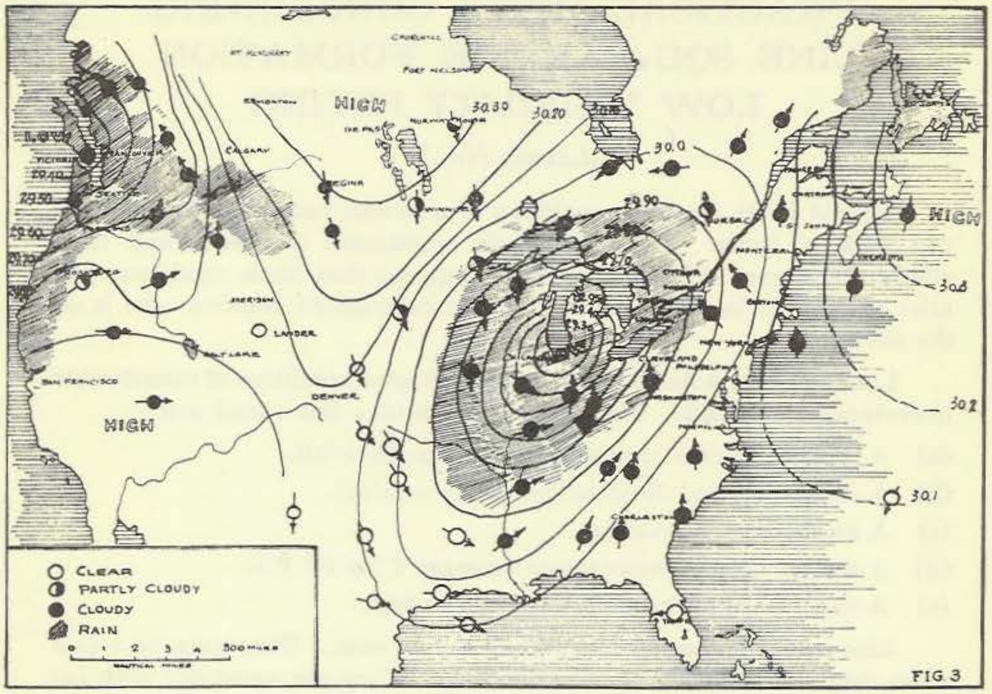
Forecasting is thus based very largely on pressure distribution and consequently it is of utmost importance that the observations should be taken with the greatest care.

COLLECTION OF WEATHER DATA

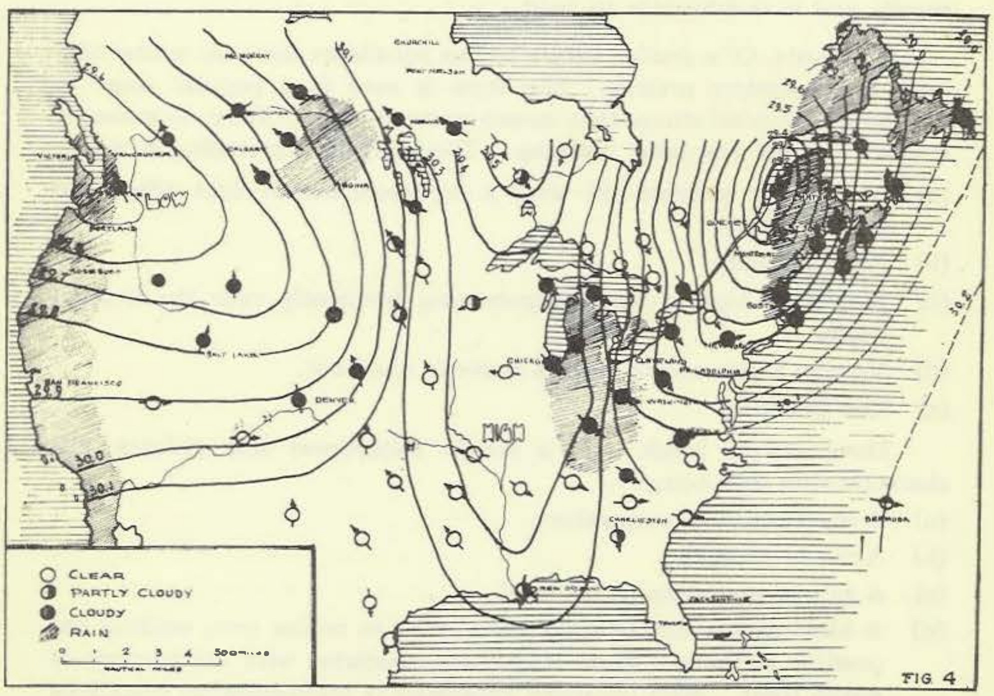
Twice a day, 8 a.m. and 8 p.m., Eastern Standard Time, observations are taken at selected stations over Canada from Atlantic to Pacific and from the boundary on the south to the Arctic in the north. These observations are telegraphed by wire or wireless to the central office, where they are all charted, and in addition the United States Weather Bureau telegraphs the observations from their stations, the Canadian service sending the observations from Canada. The chart is thus for the entire North American Continent. The preparation of a weather map is not the work of a single individual or central office, but it is the work of a vast organization and each observer in that organization is an essential part of the system; especially is this true of the observers who are at the outposts of civilization, for it is from them that the first indications of weather changes that often seriously affect the whole continent are received.

UNITS

Meteorological measurements in most English-speaking countries are: the inch of mercury, the degree Fahrenheit, a mile per hour, and an inch of rainfall.



WEATHER MAP FOR NOVEMBER 26, 1926



WEATHER MAP FOR NOVEMBER 27, 1926

PRACTICAL HINTS CONCERNING LINE SQUALLS, ICE FORMATION, LOW VISIBILITY FLYING

Lesson No. 3

Certain acute weather conditions of a serious nature to the pilot are met with at times. Frequently their appearance is sudden and their effects disastrous. However, it rarely happens that these conditions will arise without giving some warning to the experienced observer who is on the alert.

Line squalls. A line squall is a meteorological condition of considerable importance to aircraft. The characteristics of a line squall are:—

(a) A sudden increase of wind followed later by a lull.

(b) A change of wind direction (generally veering).

(c) A sudden rise in pressure.

(d) A sudden drop in temperature (average 5° to 10° F.).

(e) A long line of dark clouds with rain or hail.

Line squalls generally move from east to west. They may be 2 to 3 miles deep and as much as 200 miles long. They are associated with (a) the trough of a depression. (b) The preliminary stages of a thunderstorm, and (e) uniform isobars. It is generally impracticable to fly around line squalls and it is advisable to land.

Blizzards. Of a similar nature to line squalls we have the winter blizzards in our western prairies. This term is used in a popular sense to designate any wind-storm that causes snow to drift. Here, however, it is given a more restricted meaning. The conditions preceding it are:—

(a) Completely overcast sky with a depressed leaden light effect and poor visibility.

(b) High humidity.

(c) Relatively high ground temperatures, frequently near the freezing point.

(d) Veering winds usually from a westerly quadrant.

(e) Low pressure.

These storms break with a terrific suddenness and violence, the characteristics then being:—

(a) A severe drop in temperature.

(b) A rise in pressure.

(c) A gale of wind from the N. to E.

(d) A blinding snowfall of such intensity as to render even walking impossible at times. These storms are associated with the advance of a cold front. With improved knowledge of meteorological conditions their forecast should be a simple matter.

Thunderstorms: are generally accompanied by heavy rain or hail. They are frequently preceded by a squall. Thunder clouds are a form of cumulus cloud and are often shaped on top like an anvil. Generally they are found at a height of from 3,000 to 6,000 feet. When hail is formed they frequently extend to 20,000 feet and above. The distance of a thunderstorm from an observer may be estimated approximately by noting the number of seconds which elapse between seeing a flash of lightning and hearing the thunder. Sound travels at about 1,100 feet per second. Large summer thunderclouds are apt to be excessively turbulent in their interior. Upward air currents of 80 mph and more have been calculated as necessary for the production of some forms of hail. If to this one adds the danger of having a plane torn to shreds by hail or struck by lightning it need hardly be said that no sane pilot would deliberately fly into a large storm. One must either land or fly around them.

Hail can be seen as an advancing white wall or curtain extending from the cloud to the ground. In such a case it is advisable to run down wind and turn out of the path of the storm as even landing may not save the aeroplane from severe damage by hail.

Dust storms. A combination of prolonged dry weather and persistent S.W. winds frequently produces dust storms on the western plains. These storms, if severe, may be quite serious for the pilot who is trying to operate in this area. Dust clouds sometimes rise to a height of several thousand feet and blot out all visibility. However, they are rarely continuous over a wide area and clear patches can usually be found between the rivers of dust. Landing in a dust storm is a dangerous proceeding and had best be avoided.

Chinook winds. While we are dealing with prairie conditions it may be as well to mention the chinook winds that relieve the monotony of winter there. These are warm winds that are associated with the clear high pressure areas following a storm. A gentle S.W. wind with temperatures as high as 60° F. sweeps down over the prairies removing the snow in a few hours. This wind is accompanied by the "Chinook Arch", a solid arched cloud effect running across the sky from north to south that apparently remains stationary for days at a time.

The approach of a chinook wind is of importance to the pilot who may be operating on skiis away from his home base. However, the chinook is easy to predict, and even the experienced eye of an old timer can be relied upon to foretell its coming.

The precise meteorological significance of these winds is still a little obscure. That they are not simply warm winds from the Pacific is certain. The rise of temperature seems to lie in the increased density of the air as it flows over the mountains and is compressed in a downward movement on the east side.

Smoke haze. This may become quite dense as a result of bush fires in late summer and autumn in Canada. Its significance to the pilot lies in the fact that, as a result of it, his visibility may be reduced to the

vanishing point, and a weather chart showing good visibility conditions may be misleading. The smoke particles assist, too, in the formation of fog in low lying areas.

Fog. Fogs are due to condensation of water vapour in the air. The condensations result chiefly from the cooling of the air below its dew point by the loss of heat through radiation. An important factor in the formation of fogs is the coolness of the surface underneath the air in which the fog appears.

Ground mists at night are a serious menace to the pilot attempting to do a night landing. What appears to be a light mist on the ground may be sufficiently dense to prevent the penetration of landing lights and make landing very dangerous. These mists, however, usually roll across the ground in patches and the patient pilot will wait till a clear patch presents itself before attempting a landing.

Ice formation. This is a constant menace to flying in the early spring and late autumn in Canada. Ice formation may be brought about in two ways:—

(a) Through rain or sleet falling into a cold lower stratum of air where it will freeze and adhere to anything it touches. This is a situation that causes such havoc in winter traffic on our roads and city streets. The conditions giving rise to it are fairly easy to foretell.

(b) More difficult to detect is the ice formation on a plane due to the congealing of super-cooled water particles that may or may not be visible in the air. The critical points for the formation of ice in this way are:—

Humidity, 90% to saturation point; temperature from 32° to as low as 20° F. It has been definitely proven that water may be super-cooled to a much lower temperature than this in the form of small liquid droplets but these lower temperatures are rarely met with. The peculiar characteristic of these super-cooled droplets is that they congeal instantaneously on touching an object. The effect of ice formation on an aeroplane is three-fold: it adds to the weight; increases head resistance; and reduces lift by changing the section of the aerofoils. This last is probably the most serious result.

If ice formation on a plane is observed the pilot must quickly make up his mind to:—

(a) Change the level at which he is flying in the hope of moving out of the conditions of ice formation. If the ceiling permits, it may be possible to move into a colder upper stratum free from ice formation, and freezing sleet on the ground may be falling from a warmer upper layer.

(b) If changing altitude does not quickly free the plane from ice it is well to look for a good field and land without delay. Ice formation has been known to bring an aeroplane down in less than 15 minutes.

Reference books:—Short Course in Elementary Meteorology, by Pick
Manual of Air Pilotage.

QUESTIONS

(1) Define:

(a) Isobar.

(b) Dew point.

(c) Isotherm.

(2) What are the characteristics of a low pressure area?

(3) Under what weather conditions would you expect to find ice formation on your plane? What course of action would you follow on making such a discovery?

(4) Name ten common types of cloud formation and state the height at which each may be found.

(5) Describe the weather conditions that usually precede a line squall.

INTRODUCTION
to the
DIGEST OF AIR REGULATIONS
1938

The air engineer or air pilot operating in Canada must constantly bear in mind the four parts of Air Regulations with which he is in everyday contact and which govern all his flying activities. These are:

(1) **Air Regulations** proper, issued in pamphlet form.

(2) **Information circulars,** issued from time to time by the Minister through the Civil Aviation Branch.

(3) **Specifications** in log books and Certificates of Registration and Airworthiness stating conditions under which aircraft may be flown; or the conditions written in the airport licence.

(4) **The conditions** written or printed in each pilot's or engineer's certificate specifying the work that he may undertake by virtue of the licence he holds.

In the following pages we have given a "digest" of Air Regulations, covering the essential points briefly and in plain language. A determined effort has been made to avoid legal phraseology; but it is hoped that the law will lose none of its force through being stated in plain language. When it is stated: "Any aircraft flying abroad from Canada must have a Certificate of Airworthiness," it means just that and nothing else. Since this is a digest of **Canadian** Air Regulations, whenever a reference is made to aircraft, pilot, certificate, etc., it must be understood to mean, Canadian aircraft, Canadian pilot,—etc., unless otherwise stated.

It must also be understood that these are notes on law, simplified for the benefit of the pilot or engineer who is not concerned with the plugging of legal loopholes,—but not the law itself. This "digest" must not be quoted as law or having the force of law in any legal proceedings.

It is believed that the "Digest" will be of particular aid to the student in his interpretation of Air Regulations. For easy reference, the number in brackets at the end of each section refers to the corresponding paragraph in Air Regulations from which the section is taken.

DIGEST OF AIR REGULATIONS
PART I
INTERPRETATION

"Aircraft" means both lighter and heavier than air machines.

"Aerodyne" means heavier than air machine, power driven or glider.

"Aeroplane" means an aerodyne that is power driven.

"Aerodrome" area normally used for the arrival and departure of aircraft (not necessarily licensed).

"Airport" means an aerodrome designated by the Minister (requires a licence).

"Operator" of an airport means the holder of the airport licence, etc. (not necessarily the owner).

"Minister" means the Minister of Transport.

"Commercial Aircraft" means an aeroplane operated for money or other reward or for business purposes.

"Operator" in relation to an aircraft means the person in charge of it, including the pilot, lessee or owner.

"Air Engineer" is a person who holds a licence issued by the Minister authorizing him to act according to the terms of his licence.

"Night" means between half an hour after sunset and half an hour before sunrise in Canada. In flight beyond Canada, it means between sunset and sunrise.

PART II

REGISTRATION AND MARKING

No aircraft shall fly in Canada unless it has been registered except:

(a) Aircraft flown for experiment or test within twenty miles of an airport. (Old regulations specified three miles.)

(b) Aircraft registered in other parts of the Empire or in some other state with which Canada has a reciprocal agreement. (p.12)

An aeroplane to be **registered in Canada** must belong wholly to a British subject or subjects or to a company which has been incorporated in the Empire and of which the President or Chairman and at least two-thirds of the Directors are British subjects. (p.12)

No aircraft shall be registered in Canada unless it has been built in Canada or unless customs duties which are payable upon the importation of the aeroplane into Canada have been paid. (p.12)

No aircraft shall be registered in Canada while it is registered in any other part of the Empire or in any foreign country. (p.12)

The cost of registering an aeroplane in Canada is $5.00. On receipt of an acceptable application for registration with a $5.00 fee the Minister assigns a registration mark and after inspection may grant a certificate of registration. (p.12)

When an aeroplane is sold the registration and Certificate of Airworthiness lapse; and the former owner must notify the Department. The purchaser must send in an application for registration together with $5.00. (p.12)

When an aeroplane is destroyed or withdrawn from use the owner must notify the Department and the registration then lapses from the date of notification. (p.13)

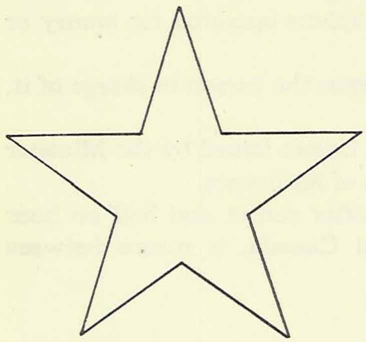
Certificates of registration must be endorsed at least once a year by the Minister of Transport to remain valid. (p.13)

A certificate of registration may be suspended or cancelled at any time for cause. (p.13)

Any aircraft flying abroad from Canada must have a Certificate of Airworthiness. (p.13)

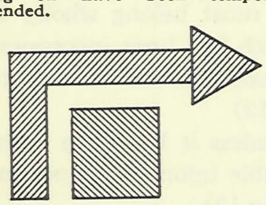
APPROACHING AN UNFAMILIAR AIRPORT

1. Look out for the following ground signs which mean:



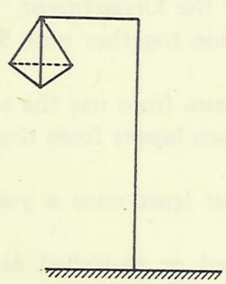
(a) A five-pointed star 50 feet across, meaning that it is an all-way field, divided into taking off and landing zones looking up wind.

(b) A red square 10 feet to a side meaning that the rules for landing and taking off have been temporarily suspended.



(c) A red square 10 feet to a side with an arrow around it pointing right which means that right-hand circuits must be observed.

(d) A red square with a diagonal cross of yellow strips 20 inches wide meaning prolonged prohibition to land.



(e) A Chinese lantern meaning that an aircraft is making an approach with a radio-electric aid to landing.

Note:–The use of the last two is optional.

All civil aircraft registered in Canada must be certified as airworthy except private aircraft flying wholly within Canada. (p.13)

Every **foreign aircraft entering Canada** must bring with it a valid certificate of airworthiness. (p.13)

Certificates of airworthiness may be limited to flying in specified areas, on specified routes, for specified periods, and upon compliance with specified conditions. (p.13)

A C. of A. must be endorsed by the Minister at least once a year to remain valid. (p.14)

An aircraft certified as airworthy may be inspected at any time by an authorized representative of the Minister. He may cancel or suspend the certificate if the aircraft is considered unsafe.

A C. of A. may be cancelled at any time by the Minister of Transport for cause. (p.14)

A C. of A. costs $5.00 for a type of aeroplane that has previously been certified as airworthy in Canada or any other part of the Empire or any country with which Canada has a reciprocal agreement. A C. of A. for any other aeroplane costs $25.00. (p.14)

Every aircraft registered for flight must bear the registration marks allotted to it. (p.14)

An aeroplane registered in Canada is allotted a combination of five letters commencing with the nationality marks "CF" and a combination of three other letters, e.g., CF-CCA. (p.14)

The letters must be painted once on the lower surface of the bottom main plane and once on the upper surface of the top main plane with the top of the letters towards the leading edge. They must also be painted on each side of the fuselage. (p.15).

The size of the letters must be such that each group shall be formed of letters of equal height as large as possible without touching the visible outline of the wings or fuselage; but the letters need not exceed four feet in height on the wings or two feet on the fuselage. (p.15)

The width of the letters must be two-thirds of the height, and the thickness one-sixth of the height. The letters must be painted in plain block characters and be uniform in shape. (p.16)

Registration markings must be displayed to the best advantage to be clearly visible and kept clean at all times. (p.16)

There is no distinctive marking for a privately owned aircraft.

PART III

AIR HARBOURS

All airports designated by the Minister must be licensed. (p.16)

An airport licence costs $10.00. (p.16)

An airport licence may be suspended or cancelled at any time for cause and ceases to be valid two weeks after change of ownership unless renewed by the new owner. (p.16)

Every airport must be marked according to regulations. (p.16)

Every airport must keep an **airport register** showing the time every aeroplane lands or takes off; also the nationality, registration marks and names of the pilot and owner. (p.17)

Every licensed airport is open to inspection by a representative of the Minister at any time. (p.17)

Every airport must have a **wind cone** or some other means of showing the wind direction.

An airport operator is permitted to charge only fees that have been approved by the Minister and a schedule of these must be prominently displayed at the airport. (p.16)

No water-craft shall cross that part of the water on the airport that it is necessary to keep clear for the alighting and taking off of other aircraft. (p.17)

PART IV

PERSONNEL

Every person, either in Canada or abroad, acting as a pilot or engineer of a commercial aircraft registered in Canada must hold a certificate authorizing him so to act. This does not apply to:

(a) Students under instruction flying under approved conditions. (p.18)

(b) Pilots and engineers of foreign aircraft flying in Canada. (p.18)

The Department issues certificates to pilots, engineers, and traffic control officers and it may limit them, in time, to specified conditions, specified purposes, specified types of aircraft, on specified routes, or otherwise. (p.18)

Every person to whom a pilot's, engineer's or traffic control officer's certificate is issued must be a British subject or a subject of a foreign country granting reciprocal rights to Canadians. (p.19)

Any certificate may be suspended or cancelled at any time for cause, which includes failure to comply with certain sections of the Canadian regulations when flying beyond Canada. (p.19)

A fee not exceeding $5.00 may be charged for any certificate issued under this Part. (p.18)

PART V
LIGHTS

An aeroplane when in flight at night shall carry the following lights:

On the **right** side a **green light** showing through an angle of 110° measured from dead ahead to the right and visible for 2 miles. (Old Regs. permitted 3 miles.) (p.20)

On the **left** a **red light** showing through an angle of 110° measured from dead ahead to the left and visible for 2 miles. (Old Regs. permitted 3 miles) (p.21)

The green light must not be visible from the left side nor the red light from the right side. (p.21)

At the **rear** and as far aft as possible, a **white light** shining rearwards showing through an angle of 140° bisected by the line of flight and visible for 3 miles. (p.21)

An aeroplane **taxiing on water or land at night** must carry full navigation lights.

An aeroplane at anchor or moored on water must carry forward where it can be best seen a white light showing all around the horizon, and visible for one mile. (p.21)

An aeroplane standing or taxiing on an aerodrome at night must carry full navigation lights.

If navigation lights fail in flight, a landing must be made at the first safe opportunity.

Airport Lighting and Marking.

Every airport licensed for night flying must have the following lights:—

Aerodrome beacon. (Rotating optional). (p.29).

All obstructions on the airport and if possible within one mile of the airport to be indicated by fixed red lights. (p.29)

Lighted wind cone or landing T indicator.

Landing area must be lighted by a flood light or by contact lights spaced 165 feet apart down the sides of the runway; and at least two green contact or range lights on each runway.

For emergency; lights to be laid out in the formation of a T with the long arm composed of four lights, in a line not less than 820 feet in length.

Boundary lighting to be marked by fixed white or yellow lights 300 feet apart.

No dangerous or confusing lights to be permitted in the neighborhood. (p.29)

An airport must be marked so as to show the useful landing areas both from the air and on the ground. (p.25)

Ground Marking

Where a landing T is used, it indicates that it is compulsory to land or take off toward the cross arm of the T irrespective of wind direction. (p.25)

At certain airports the landing area may be regarded as being divided into two equal zones by a vertical plane in the direction of landing, one for landing and one for departure. The zone on the right looking up wind is reserved for landing and the zone on the left for departure. Where this rule applies the airport is marked with a five pointed star 50 feet in diameter. Every aircraft landing at such an airport shall land as far as possible to the left of the landing zone, but leaving clear on its left any other aircraft which has already landed or is landing, and shall take off as far as possible to the left of the taking off zone, but leaving clear on its left any other aircraft which has already taken off. (p.26 and 41).

Signals to Aircraft Taxiing.

An **intermittent green light** directed toward an aircraft on the ground authorizes an aircraft to move or taxi. (p.33)

A **continuous green light** gives authority for an aircraft to take off. (p.33)

An **intermittent red light** forbids taking off or any movement of an aircraft on the ground. (p.33)

SIGNALS

The call sign of an aircraft shall be the complete group of five letters constituting its nationality and registration marks.

The firing of a red rocket or the flashing of a red light from the ground is the signal that a landing must not be made at that time. (p.35)

To warn an aircraft that it is in the vicinity of a prohibited zone, and should change its course, the following signals shall be used:—

By day: three discharges, at intervals of 10 seconds, of a projectile showing, on bursting, orange smoke, the location of the burst indicating the direction the aircraft should follow. (p.36)

By night: three discharges, at intervals of 10 seconds, of a projectile showing, on bursting, orange lights or stars, the location of the burst indicating the direction the aircraft should follow. (p.36)

To require an aircraft to alight, the following signals shall be used:—

By day: three discharges, at intervals of 10 seconds, of a projectile showing, on bursting, black smoke. (p.35)

By night: three discharges, at intervals of 10 seconds, of a projectile showing, on bursting, white stars.

In addition, when necessary to prevent the alighting of aircraft other than the one ordered, a searchlight, which shall be flashed intermittently, shall be directed towards the aircraft whose alighting is required. (p.35)

No unauthorized lights, signals, or markings may be used or displayed.

Distress Signals

1. By radiotelegraphy:
   S.O.S./S.O.S./S.O.S./D.E./CF-CCA/CF-CCA/CF-CCA
2. By radiotelephony (spoken):
   MAYDAY/MAYDAY/MAYDAY/D.E./CF-CCA/CF-CCA/CF-CCA
3. By visual signalling:
   (a) S.O.S./S.O.S/S.O.S/D.E./CF-CCA/CF-CCA/CF-CCA
   (b) Series of red lights fired three times at short intervals. (p.31)

Urgency Signals

(Used to give notice of difficulties which compel an aeroplane to land without requiring immediate assistance.)

1. By radiotelegraphy:
   PAN/PAN/PAN/D.E./CF-CCA/CF-CCA/CF-CCA
2. By radiotelephony (spoken):
   PAN/PAN/PAN/D.E./CF-CCA/CF-CCA/CF-CCA
3. By visual signalling:—
   (a) By day: a succession of white pyrotechnical lights.
   (b) By night: same as (a), or a succession of intermittent flashes of the navigation lights. (p.32)

Safety Signals

(Used in sending a message regarding the safety of navigation or meteorological warnings.)

1. By radiotelegraphy:
   T T T/T T T/T T T/D.E./CF-CCA/CF-CCA/CF-CCA (p.32)
2. By radiotelephony:
   SÉCURITÉ/SÉCURITÉ/SÉCURITÉ/D.E./CF-CCA/CF-CCA/CF-CCA
3. By visual signalling:
   International visual signalling procedure, by signalling apparatus or flags. (p.33)

RULES OF THE AIR

Very Important.

Risk of collision is deemed to exist when the bearing and angle of elevation of an approaching aircraft do not appreciably alter. (p.36)

When two aircraft are meeting head-on or nearly head-on each shall alter its course to the right. (p.37)

When two aircraft are flying **on courses which cross,** the one on the right has the right-of-way. The one on the left must alter its course so as to pass behind the other. (p.37)

When one aircraft is **overtaking** another, it must keep clear to the right of and not pass above or below the over-taken aircraft. If the side

lights of the slower plane cannot be seen, the rules applying to overtaking aircraft must be followed. In daytime, if there is any doubt, the rules for overtaken aircraft should be followed; and the overtaking aircraft must keep out of the way. (p.37)

Where the rules require an aeroplane to alter its course and give way, it must not pass in front of the other aeroplane. (p.38)

Aircraft must fly on the right side of a recognized air route. (p.38)

Aircraft on land or water, about to take off, must not attempt to take off until there is no risk of collision with alighting aircraft. (p.38)

An aeroplane flying a compass course along a recognized route must keep one mile to the right of it. (p.38)

An aircraft following a recognized course marked, such as a road, must keep at least 1000 feet to the right of it. (p.38)

All well recognized routes must be crossed at right angles. (p.38)

TRAFFIC IN THE VICINITY OF LICENSED AERODROMES.

Rules for Landing.

When coming in for a landing an aeroplane must:

Approach from the lee side of the field.

Land into the wind or according to landing T if one is used.

Come in straight for at least 1000 yards and toward the landing zone.

Keep clear of other aircraft coming in to land at a lower level; and, while in the air, observe the law governing overtaking aircraft.

Land as far as possible to the left of the landing zone, (which is on the right), but keeping on its left other aircraft which have landed in front of it.

Rules for Taking off

Taxi in the neutral zone to the extreme lee side of the taking off zone.

Use the full length of the field in taking off.

Take off into wind.

Take off from the left side of the taking off zone, (which is on the left) but to the right of aircraft taking off in front of you.

Do not take off if there is risk of collision with aircraft landing.

Fly straight to the edge of the aerodrone before turning and observe circuit law: i.e., turn left if you turn.

Get off the aerodrome as soon as possible.

Flight over or in the Vicinity of the Landing Area

Flying over an airport at less than 2000 feet except for landing or taking off, is prohibited. (p.39)

No right-hand turns within 6000 feet of an airport unless at a greater height than 2000 feet. (p.39)

No aerobatics nearer than five miles or 6000 feet.

Turns before landing or after taking off must always be left-hand and clear of the landing area unless by special provision. (p.40)

A straight approach of at least 3000 feet must always be made in landing. (p.40)

An aircraft must always land on the right side of another aeroplane that has landed or is about to take off. (p.40)

(c) and (d). An aeroplane landing or taking off must leave clear on its left any aeroplane that has landed or is taking off. (p.40)

(e). Every aeroplane landing or taking off shall leave a reasonable space on its right for other aeroplanes to land or take off. (p.40)

(f). Landing or taking off simultaneously, unless pre-arranged, is prohibited.

(g). Two aircraft taking off simultaneously by pre-arrangement shall be regarded as one aircraft. (p.41)

On land airports having a ground control, no aeroplane shall take off until it has received the prescribed signal. (p.41)

(a). Every aircraft taxiing on an aerodrome shall normally do so in the direction of landing; and turns must be made to the left in such a manner as to give free way to other aircraft landing or taking off, and in conformity with general air traffic rules. (p.41)

(b). The rules for land aerodromes apply equally to water aerodromes, subject to paragraph 47, part V. (p.42)

Every aircraft manoeuvring under its own power on the water shall conform to the International Regulations for Preventing Collisions at Sea, and for the purposes of these regulations shall be deemed to be a "steam vessel". (p.42)

When an aircraft of a contracting State is in the territory of a non-contracting State, the provisions of Part V shall apply to it only in so far as they do not conflict with the laws of the non-contracting State. (p.42)

(The rule requiring aircraft to keep at least 200 yards apart no longer applies.)

PART VI
DANGEROUS FLYING

An aeroplane **flying over a city** or populous area must keep enough height to glide clear in case of engine failure. (p.43)

Trick Flying over towns, cities or populous areas is forbidden. (p.43)

Trick flying over race meetings, regattas or public gatherings is forbidden unless authorized in writing by the promoters concerned and authorized by the Minister. (p.43)

Low Flying, near persons or dwellings, that is dangerous to public safety, is forbidden. (p.43)

It is forbidden to drop any article from an aeroplane that might cause damage or injury. Water or fine sand may be used as ballast. (p.43)

No aeroplane shall be rolled, spun, looped or put through any evolution involving unnecessary risk, unless the pilot is alone in it, or unless the pilot is an authorized instructor giving instruction.

Entering or leaving an aeroplane in flight is forbidden unless to make a parachute jump. (p.43)

Gymnastic displays, such as wing walking, etc. are forbidden.

PART VII

SCHEDULED AIR TRANSPORT SERVICE

No scheduled air transport service on an international or interurban route shall be operated unless it has been authorized by the Minister who may designate any route as requiring a licence. (p.44)

(A separate licence issued by the Board of Transport Commissioners for Canada under the Transport Act covers the flying of aircraft on schedule from a standpoint of public convenience and necessity, insurance and financial responsibility.)

PART VIII

GENERAL PROVISIONS

Explosives are forbidden on passenger aeroplanes.

All explosives must be marked as such.

Mails must not be carried without the authority of the Post Master General. (p.44)

Passengers must not be flown from or to an unlighted airport after dark nor flown over a route which is not adequately lighted and approved by the Minister for night flying. (p.44)

The boundary of a prohibited area commences at a point where a line from the aeroplane to the nearest point of the prohibited area makes an angle of 20° to the vertical. This includes penitentiaries. (p.45)

An aeroplane must not carry a **camera** or take photographs in Canada unless it is registered in Canada or some other part of the Empire. (p.45)

Radio must not be carried without a licence.

A commercial aircraft must be **inspected by an air engineer** every day that it is in use. If the first flight starts before 8 a.m. then an inspection after 12 noon on the previous day, or after the last flight on the previous day, which ever is later, will do.

The **engineer must certify** airworthiness in the Journey and Aircraft log book, and the pilot must counter-sign this. No member of a crew of an aeroplane is permitted to fly while in a state of intoxication. (p.46)

Before flight, the pilot of a commercial aircraft must enter in the log book the weight of the load carried. He is responsible that the load carried does not exceed that specified in the C. of R. and that it is secured.

Every aircraft in flight must carry its C. of A., C. of R., the licencesof all the crew requiring licences, and a Journey log book. (p.47)

Every commercial aeroplane must have:

> **A Journey and Aircraft log book** containing a full description of the aircraft, the instruments and accessories carried in it, and showing the names, nationality and addresses of the owners. A fully detailed record of the life of the aircraft, overhauls, repairs and replacements must be shown; also the loads carried, the hours flown, and the number of passengers.

> **An engine log book** for each engine giving full description of engine, accessories, and running data. It must show a detailed

record of the life of the engine, including hours run, overhauls, repairs and replacements.

Entries in log books must be made in ink as soon as possible after the events they record.

Entries to be made in the journey and aircraft log book may first be made in a rough note book, but must be permanently entered within 24 hours after the events recorded.

The pilot or other competent person is responsible for making these entries.

All entries must be signed by the person by whom they are made.

Erasures must not be made nor leaves torn from any log book. (p.49)

Every commercial aircraft owner must make a return to the Minister annually, on or before the 31st of January, giving such particulars of the operations of the aircraft as may be required. (p.49)

A copy of the C. of A. and the C. of R. must be kept in a pocket at the end of the aircraft log book. (p.49)

Every holder of a licence must produce it on demand by a peace or customs officer or representative of the Minister. All log books must likewise be produced on demand. (p.49)

If an aeroplane flies in breach of regulations, the owner, as well as the pilot and the crew, is liable therefor. (p.49)

Any person who obstructs an officer in the exercise of his duties under these regulations is guilty of a breach of regulations. (p.50)

IMPORTANT. If any person is **killed or injured** in or by an aeroplane, the pilot or the owner must report the date and place of the accident to the Minister by telegram immediately. A full report must be mailed to the Minister by the pilot or owner as soon as possible. (p.50)

If an aeroplane is damaged so that more than running repairs or replacements are necessary, the owner or pilot must make a written report to the Minister, giving full particulars of the damage. (p.50)

An aeroplane involved in an accident causing death or injury **must not be removed** without the permission of the Minister. (p.50)

It may be moved, however, to extricate persons, remove mails or prevent destruction by fire. (p.50)

No aircraft of a state with which Canada has not concluded a convention may fly over Canada without the written permission of the Minister. (p.49)

The regulations do not apply to military aircraft flown by an officer on duty.

INTERSTATE FLYING

An aeroplane flying into Canada **from abroad** must make its first landing at a customs airport. An aeroplane flying abroad from Canada must leave from a customs airport and must not land in Canada again without first completing its journey abroad.

No aircraft proceeding from or entering Canada shall carry **arms or explosives** or munitions of war.

An aircraft must not have secret places for concealing goods when entering or leaving Canada.

On an outward bound aircraft, the pilot must make a statement to the customs collector showing the destination, description of aircraft, pilot's name, cargo, passengers and crew.

An outward bound flight must not be undertaken until the pilot has received a certificate-of-clearance from Customs.

If an inward bound aircraft is compelled to make a forced landing at an airport that is not a customs airport, the pilot must immediately report to the airport manager or to the police. In the event of a forced landing by an inward bound aircraft, the pilot must communicate with the local police immediately and the customs officials at the earliest opportunity.

INTERSTATE FLYING TO THE UNITED STATES

A Canadian aircraft entering the United States must:

Carry a C. of A., a C. of R., licences for all the crew, and journey and aircraft log book.

Must get customs clearance; take off from a customs airport; and fly to a customs airport.

The Pilot must wire ahead to the customs airport at the point of entry, stating the estimated time of arrival and giving description of plane and number of passengers.

Canadian aircraft must not carry **cameras** into the United States nor take photographs from the air while in the United States.

A Canadian aeroplane carrying passengers or cargo to a distant point in the United States may land at a customs airport and carry on to its destination with its cargo or passengers, but must not pick up passengers or cargo en route.

A Canadian aeroplane is permitted to take on passengers or cargo destined to Canada at different airports in the United States on the return trip to Canada, if they are coming through to Canada.

American aircraft flying to or in Canada are permitted exactly the same privileges and are bound by exactly the same restrictions as Canadian aircraft flying into or in the United States.

An application for a private pilot's licence must be accompanied with a fee of $2.00. At present there is no charge for an engineer's licence or a commercial pilot's licence.

A private pilot, to keep his licence in good standing, must be medically examined and found fit at least once a year and after every serious accident or sickness. A commercial pilot (male) to keep his licence in good standing must be medically examined and found fit at least every six months. Commercial Pilots (Female) every four months.

These last conditions are printed in the front of every pilot's licence and, for the holder, they constitute Air Regulations.

CAN YOU ANSWER THE FOLLOWING QUESTIONS ON AIR REGULATIONS?

1. What is a commercial aeroplane? What is meant by "night" when flying (a) in Canada (b) abroad?
2. What aeroplanes must be registered in Canada? What are the exceptions?
3. You have bought and wish to operate a commercial aeroplane of an approved type in Canada. What certificates do you need? What do they cost? How do you obtain them? What combinations of letters are used to show nationality and registration of Canadian aircraft?
4. For what period are C. of R. and C. of A. valid? How are they kept in good standing? How is a privately owned aeroplane marked? Does it need a C. of A. in Canada? In the U.S.A.
5. May you fly a private aeroplane without a C. of R? Without a pilot's certificate?
6. What is the "Circuit law" at a licensed airport?
7. What persons on board an aeroplane must have licences?
8. What lights must an aeroplane carry at night? (a) In the air? (b) taxiing on water? (c) standing or taxiing on an aerodrome? (d) at anchor? (e) drifting out of control?
9. What signals are used to: (a) ask and give permission to land? (b) refuse permission to land? (c) indicate emergency landing from the air?
10. What constitutes risk of collision? What are the rules for (a) meeting head on? (b) crossing courses? (c) overtaking?
11. What are seven rules that must be observed in taking-off from a licensed airport?
12. There are eight rules for landing at a licensed airport, what are they?
12. There are eight rules covering dangerous flying, what are they?
13. As pilot of a commercial aeroplane, what must you do before flying to the U.S.A.?
14. What is the law in respect to the daily inspection of aircraft?
15. What logbooks must an aeroplane have? What entries are made in them? By whom and in what manner?
16. Who is responsible that an aeroplane is not overloaded? How do you ascertain what load an aeroplane may carry?
17. What do you do if your aeroplane has (a) Had its propeller broken? (b) Had one wing damaged beyond repair? (c) Taxied into and injured a by-stander?
18. What rights have: (a) Canadian aeroplanes flying into the U.S.A.? (b) What restrictions are placed on them? (c) What rights and restrictions have American aircraft flying in Canada?

SUMMARY OF REQUIREMENTS FOR ISSUE OF PILOT'S LICENCES

PRIVATE PILOT'S LICENCE. Application form with 3 photographs 2″ x 3″, $2.00 fee, spin certificate, and medical category of "B" or better within one year. Age over 17 years.

Flying Tests: four landings from 1,500′ coming to rest within 50 yards of mark. One landing from 5,000′ coming to rest within 100 yards of mark. Five figure "8" turns. Written examination on Air Regulations.

LIMITED COMMERCIAL LICENCE. Application form with 3 photographs 2″ x 3″ and proof of 50 hours flying experience. Medical category up-to-date within six months, "A" category. Age 19 to 45 years.

Flying Tests: cross-country 200 miles round trip. Four landings from 1,500′ and one from 5,000′ all upon signal. Spin. Five figure "8" turns.

Written examinations on: theory of flight, Engines and Rigging, air pilotage and meteorology, and Air Regulations.

Practical test on: engines, rigging, and compass swinging.

TRANSPORT LICENCE. Application with proof of 500 hours flying time, 3 photographs, and medical up-to-date. Age 23 to 45 years.

Flying tests: landing tests. Cross-country 200 miles. Endurance test at 12,000′ for one hour. Three night flights of 15 minutes each. Instrument flying for 30 minutes. Spins.

Practical Tests on: engines, rigging, and compass swinging.

Written examinations on: theory of flight, engines and rigging, air pilotage and meteorology, and Air Regulations.

AIR ENGINEER'S CERTIFICATES A AND C: Applicant must be a British subject with two years practical experience; three letters of competency from previous employers verifying the record of practical experience. Practical tests on: (a) Adjustment of rigging for flight, (b) Repairs to fabric, wood and metal parts, (c) Running repairs of aero engines. The written or oral examination is on the following subjects: (a) Assembly and rigging of aircraft, (b) Construction and operation of aero engines, (c) Carburetors, magnetos, and other accessories, (d) Causes of faulty running of engines and correction, (e) Lubricating oils used in aero engines, (f) Equipment necessary in aircraft operating in Canada, (g) Capacity, disposition of useful load in aircraft, (h) Air Regulations, (i) Aircraft instruments.

AIR ENGINEER'S CERTIFICATES B AND C: The requirements are the same as above except that the applicant must have two years factory experience, and generally higher qualifications.

MEMORANDA

MEMORANDA